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COALS OF THE NORTONVILLE QUADRANGLE

BY

A. F. CRIDER

1914

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NORTONVILLE QUADRANGLE

LOCATION.

The Nortonville quadrangle lies in the western part of Kentucky between 37° and 37° 15′ north latitude and 87° and 87° 15′ west longitude, and embraces parts of Hopkins, Christian, Muhlenberg, and a small area of Todd Counties. It is so named from the principal town of this area. It is just east of the Dawson Springs and south of the Madisonville quadrangles, the geology and natural resources of which have been described in previous reports, and is bounded on the east by the Drakesboro quadrangle.

PREVIOUS REPORTS.

The first description of the coals of this region was by Dr. David Dale Owen, in Vol. I., Kentucky Geological Survey, 1856. In that report he describes coals Nos. 9, 11, and 12, which were then worked in a limited way in the hills west of Mortons Gap, on Pond River north of Bakersport, and in the hills near the present site of Graham. The coals at that time had not received the designations by which they are now known, but his correlations of these three coals in Hopkins and Muhlenberg Counties were correct.

In Vol. III., 1857, Dr. Owen describes the various coals found in Western Kentucky from No. 1 to No. 12, inclusive, and gives a general connected section of the Pennsylvanian rocks from the Bell or No. 1 B. coal to 50 feet above coal No. 18, an interval of 1,350 feet. Of this interval, 550 feet was above what he called the Anvil Rock sandstone. He placed the thickness of the Pennsylvanian rocks, exclusive of the basal pebble-bearing sandstone, at about 1,400 feet.

In Vol. I., Part VI., New Series, Kentucky Geological Survey, 1876, Mr. Charles J. Norwood discusses in a

general way the geology adjacent to the Louisville, Paducah and Southwestern Railroad (now the Illinois Central Railway), which passes through the northern part of the Nortonville quadrangle.

In Vol. IV., Part VII., New Series, 1878, Mr. Charles J. Norwood discusses the geology and gives a number of sections along the St. Louis and Southeastern Railroad (now the Evansville Branch of the Louisville & Nashville Railroad), in the region of Earlington, Nortonville, Mannington, Empire and Crofton.

In Bulletin No. 17, Kentucky Geological Survey, 1912, Dr. L. C. Glenn describes the geologic structure and coals in the region of Nortonville, Oak Hill, Mannington and Empire and correlates the coal at the last two places with the Dawson Springs and Charleston coals.

Mr. F. M. Hutchinson, in Bulletin No. 19, Kentucky Geological Survey, describes the coals in the Central City, Madisonville, Calhoun and Newburg quadrangles and gives a large number of records of shafts and boreholes in various parts of these quadrangles.

TOPOGRAPHY.

General Features.

The topography of the Nortonville quadrangle is of an old plain rising to a maximum elevation of 850 feet above sea level, in the south-central part, and sloping gradually to the north toward the Ohio River. The lowest elevation is along Pond River, at the northern edge of the quadrangle, where the elevation is approximately 375 feet. The total relief from the tops of the highest hills to the lowest valleys is approximately 475 feet.

The plain has been greatly dissected by stream erosion until there are no large areas of level land left on its old surface. Even the narrow ridges left have been dissected into a series of hills and saddles similar to the topography of the mountainous regions of Kentucky, but on a greatly reduced scale. The upper courses of the smaller streams have deeply cut channels with narrow valleys which merge into wider valleys as the larger

streams of the region are approached. The roughest type of topography is in the region adjacent to the outcrop of the base of the Pennsylvanian and top of the Mississippian rocks and to a short distance south of this outcrop, where the heavy sandstone in the upper part of the Mississippian comes to the surface and has prevented rapid erosion.

In the northern and north-central parts of the quadrangle thick deposits of shale coming below the No. 9 coal have been worn away more uniformly, giving rise to comparatively level areas, such as those found in the region of White Plains and in the region between Mortons Gap and Pond River. The few outstanding hills and ridges of this region are capped with sandstones which have preserved them from rapid erosion.

The valleys of Pond River, Drakes Creek and the West Fork of Pond River are from one-half to two miles wide. These valleys are subject to overflow and large areas are still uncleared on account of poor drainage. Excessive high water in Ohio River backs the water up Pond River to an elevation of nearly 400 feet above sea level.

Drainage.

Green River receives the entire drainage of the Nortonville quadrangle through Pond River, with the exception of about four square miles in the extreme southwestern corner of the quadrangle, lying just west of the Hopkinsville and Crofton road, which drains into Tradewater River. Pond River enters the quadrangle just north of the southeast corner, flows in a general northwest direction, and leaves the quadrangle on the north near the center from east to west.

The general course of Pond River is fairly straight, showing that in its early history it was a rapid stream, which cut its way with little difficulty down the northward slope of the slightly inclined rocks of this region. Its present channel, however, is that of an extremely crooked stream, which meanders back and forth across its wide flood plain in the manner of a stream that has practically reached base level and lost its degrading action. There is evidence that at one time its valley was scoured out

to a depth of 75 to 100 feet below the present flood plain and subsequently filled to its present level.

Drakes Creek, West Fork, Coal Creek and Buck Fork are the four largest tributaries entering Pond River from the west. Long Creek and Jarrel Creek are the only two streams of importance entering it from the east.

Pond River at its normal stage is a very sluggish stream carrying a small volume of water, and having somewhat less than fifty feet fall from where it enters to where it leaves the quadrangle. Any attempt, therefore, at pounding the water for the development of water power would flood a large area of alluvial soil, which, at some future time, and under proper drainage, will become a most valuable addition to the agricultural wealth of the region.

CULTURE.

The principal towns of the Nortonville quadrangle are Nortonville, Crofton, Mortons Gap, White Plains, and Graham, each with a population of less than 500. Nortonville, Mortons Gap, and Graham are mining towns. Agriculture and coal mining furnish the principal employment of the people. In the south-central and western parts of the quadrangle the country is very rough, and the population is sparse. In the region around Crofton, White Plains, and east of Mortons Gap the country is more level and more attention is paid to agriculture.

Two railroads, the Illinois Central and the Louisville & Nashville, traverse this quadrangle. The Illinois Central crosses the quadrangle in an east-west direction near the southern boundary of the area underlain by Nos. 9 and 11 coals. A spur of this road from Graham station connects the large coal mines at Graham with the main line and furnishes an outlet for the coal. The Louisville & Nashville Railroad traverses the entire length of the quadrangle from north to south, near the western border, and furnishes an outlet for the coals mined at Mortons Gap and Empire. The mine at Nortonville has spurs to both the Illinois Central and the Louisville & Nashville Railroads. The entire area

is accessible by public and private roads. The Hopkinsville road from Crofton to the southern boundary of the quadrangle, and the Greenville road from Crofton to within a mile of Pond River are macadamized. The remainder are dirt roads, many of which become almost impassable in long rainy seasons.

GEOLOGY.

STRATIGRAPHY.

Within the area of the Nortonville quadrangle the rocks represented on the accompanying map by the uncolored area belong to the Mississippian, while those on the colored area belong to the Pennsylvanian. The Pennsylvanian are the coal-bearing rocks of this region, and consist of shales, sandstones, thin limestones, clays and coals.

There are three distinct coal seams mined on a commercial basis in the Nortonville quadrangle. These are, in ascending order, the Mannington or Empire, the No. 9, and the No. 11 coals. No. 12 coal has been opened in a few places, but has a poor roof and is not worked at present. What is, perhaps, the Baker or Nebo coal was formerly worked by drift at Nortonville, but it was of such poor quality and had such a rotten roof that it was soon abandoned.

In addition to the Mannington coal, one or two of the thinner coals coming below No. 9 coal have been opened and worked as country banks and will be described later.

The map accompanying this report is based on the topographical map issued in co-operation by the Kentucky Geological Survey and the United States Geological Survey, and was made primarily for a delineation of the various coal seams and associated rocks of this region. The detail shown in the outcrops of Nos. 9 and 11 coals and the basal member of the Pennsylvanian was made possible only by such a map. Owing to the fact that development of the coals below No. 9 in this quadrangle is restricted to one or two coals in two small areas, with the natural exposures separated by long distances, no

attempt has been made to show the continuous outcrop of these lower coals on the map.

The Mississippian are the oldest rocks outcropping in the region under discussion and form the bed rocks on which the Pennsylvanian rocks were unconformably deposited. They are made up of limestones, calcareous and siliceous shales, and sandstones. They form the surface of the southern part of the quadrangle and are shown on the map accompanying this report as the uncolored area.

The Mississippian base on which the Pennsylvanian rocks rest is very irregular. In places it may consist of a limestone, while in a short distance the underlying rock may be a sandstone or perhaps shale. This irregularity is due to an unconformity. That is, the Mississippian rocks formed a land surface which was subjected to a period of erosion followed by a submergence before the Pennsylvanian sediments were deposited. The erosion agencies cut away the surface unequally, leaving exposed a sandstone, a shale or a limestone. The relief of the base (the amount of erosion) upon which the Pennsylvanian rocks rest is 100 to 150 feet.

South of the margin of the continuous area of the Pennsylvanian are occasional remnants or outliers of Pennsylvanian which indicate that these rocks once extended further south than they are now found. These outliers in places are 3 to 4 miles removed from the main body and are the remnants of a once larger area of these rocks which have been separated from the main body by stream erosion.

The Pennsylvanian rocks underlying this region are those formed by deposition and cementation of sediments and known, therefore, as sedimentary rocks. These, in the order of their abundance, are shales, sandstones, coals, and limestones. The sediments composing these rocks are mainly such as are at present being formed at the mouth of streams in lakes and oceans. It is evident, therefore, that this region, at one time, was the margin of a vast basin of water into which streams from an adjacent land area carried sediments of mud and sand. The limestones are usually thin and made up of calcareous materials and are formed in deeper

seas and further removed from the shore line than shales and sandstones.

To give an idea of relationship of the rocks of this region to those forming the crustal part of the earth, the following complete geologic column is here given, the oldest system being at the bottom:

Group.	System.
Cenozoic	Quaternary. Tertiary.
Mesozoic	Cretaceous. Jurassic. Triassic.
Paleozoic	Permian. Pennsylvanian. Mississippian. Devonian. Silurian. Ordovician. Cambrian.
Archeozoic	Archean.

The bed rocks of this quadrangle belong to the Pennsylvanian and the Mississippian systems of the Paleozoic group. Since this report is confined to a discussion of the coals and the rocks of Pennsylvanian age, the geology of the Mississippian rocks will be discussed only in so far as it relates to the contact between the Pennsylvanian and the Mississippian.

The following table shows the full thickness of the Pennsylvanian rocks and the relationship of the different members to the coals in the Nortonville quadrangle:

General Section.

	Feet.	Inches.
Sandstone	60	
Shale	3	
Coal (not everywhere present)	5	
Fire clay	2	
Shale	36	
Sandstone	30	
Shale	11	
Coal	thin	

	Feet.	Inches.
Fire clay	3	
Sandstone	20	
Shale	30	
Coal (No. 12)	5	
Fire clay	1	
Limestone	4	
Clay shale	2	
Coal (No. 11)	6 to 7	
Fire clay	2	
Shale	18	
Sandstone and shale	40	
Shale	15	
Black slate	3	
Coal (No. 9)	5	
Fire clay	2	
Limestone	0	6
Shale	10	
Coarse yellow sandstone	20	
Clay shale	1	
Coal	1	
Dark, mottled, blue limestone	2	
Gray shale	10	
Sandstone	20	
Shale	20	
Black slate	3	
Coal (No. 8)	1	6
Clay	6	
Sandstone	50	
Coal (No. 7)	2	10
Sandstone, hard	50 (?)	
Thin bedded sandstone	30	
Shale	20	
Sandstone	20	
Coal	thin	
Shale	30	
Sandstone, hard	40	
Shale, in places cut out	10	
Calcareous shale or rotten limestone containing marine fossils, sharks' teeth, etc.	0	6
Coal	3	6
Blue shale weathering to a chocolate color	30	
Shaly sandstone	3	
Gray shale containing thin bands of sandstone	18	
Laminated sandstone	10	
Shale	12	
Limestone	3	

	Feet.	Inches.
Coal (Cates)	3	6
Blue shale	8	
Sandstone	14	
Siliceous shale	20	
Coal (Mannington)	3 to 4	
Shale containing thin sandstones	70	
Limestone	1	
Sandstone	40	
Coal (Mud River, not everywhere present)	3½ to 4	
Fire clay	3	
Dark blue shale containing thin coal	60	
Sandstone	4	
Shale with thin sandstones	150	
Sandstone	10	
Sandstone containing thin shales and coal	20	
Basal Pennsylvanian-pebble bearing	105	
Limestone	thin	

The foregoing section is a composite one made up from surface tracings and drill records. The part below No. 9 coal is entirely of surface measurements obtained along the Louisville & Nashville Railroad between Crofton and Nortonville, and in the region south of White Plains. The measurements above No. 9 coal were principally from drill records in the faulted region of Nortonville and Concord school house, where the highest rocks of the region come to the surface.

The difficulty of making a general section that is representative of the conditions that exist over a large area arises from the fact that frequently several surface measurements, or carefully kept drill records, made between easily recognized horizons, over a very limited territory, vary widely. This is shown by comparing the Lacy and the Concord school house records which were made by a careful driller for the St. Bernard Mining Company. These wells are just one mile apart, but the details of the records vary widely. However, while the details may vary, there is generally a trustworthy uniformity in the intervals between the best known coals and certain other well marked horizons which make the general sections of value.

GEOLOGIC STRUCTURE.

The rocks of this district form a portion of an extensive spoonshaped trough or basin on every side of which the formations dip down to a central deepest part which is located in Central Illinois. Before the rocks were disturbed and broken by later movements and fault zones there was, therefore, a gradual dip on all sides toward the central portion of this synclinal basin. The Western Kentucky coal field forms the extreme southeast end of this basin, which, at one time, extended somewhat farther to the southeast than at present. The general dips from the edges toward the center of the basin have here, in many cases, been locally changed by later folding and warping and by strongly marked fault zones, this being particularly true with reference to the area comprised within the Nortonville quadrangle.

FAULTS.

CROFTON FAULT ZONE: There are two fault zones crossing the quadrangle from east to west. The most pronounced fault zone enters the quadrangle from the west in the region of Crofton, extends slightly north of east and passes out of the quadrangle on the east in the region of Long Creek. It is traversed by a series of approximately parallel faults, no one of which can be traced entirely across the quadrangle. There is usually, at any one place in the fault zone, a primary fault on the south with one or more secondary adjustment faults to the north. The secondary fault at one place may become the primary fault east or west of that point.

The majority of the faults are of the "normal" type, accompanied in places by lateral pressure. In the deep cut one mile north of Crofton there is evidence of lateral pressure being exerted from the north where a bed of Pennsylvanian shales is thrust over the underlying sandstone for a distance of 125 feet.

In width the main fault zone extends from 1 mile north of Crofton to ½ mile south of Empire station, a distance of about 1½ miles. In the West Fork and Pond River districts the zone is about 2 miles wide.

The major fault is the one shown on the maps as the Crofton fault. The amount of displacement is sufficient to bring the Empire coal down 100 feet below the base of the Pennsylvanian rocks and is approximately 467 feet. The rocks in the main fault plane stand vertical and gradually flatten out to the north. At Empire station the dip is about 10 degrees to the north. The effect of the fault and these rapid dips is to expose the edges of about 500 feet or more of strata in a distance of less than two miles. A cross-section (Fig. 1) made along the east side of the railroad cut, from the big fault 1 mile north of Crofton, to a point 1 mile north of Empire station, shows the relationship of the different strata, dips, folds and faults. The rocks just north of the main Crofton fault dip strongly away from the fault to the north for a distance of about ½ mile. Then in a distance of a few hundred feet the northward dip is interrupted by two parallel faults with another parallel fault a half mile still further north. Just north of the third fault the rocks are strongly folded and broken on the south.

The nature of the faulting in this region seems to be a combination of normal faulting accompanied by lateral pressure exerted from the north. The rocks were apparently first greatly tilted to the north as a result of the normal displacement in the main Crofton fault. As this great mass of rocks on the north side of the fault dropped it was accompanied by a strong lateral pressure from the north which broke some of the rocks and shot them over the underlying strata, as shown in figure 1, near the main fault. To equalize the strain to which the rocks were subjected adjustment faults began to develop north of the main fault, as exemplified in the three faults north of the Crofton fault. These four approximately parallel faults have formed a series of monoclinal blocks with the downthrow in opposite direction to the dip. That is, the block bordering the main Crofton fault has had the greatest displacement and each block to the north a correspondingly smaller throw. The effect of this kind of faulting on any particular coal seam, sandstone or limestone, is to cause it to repeat

itself in crossing the country at right angles to the fault line.

This is the case with the pebble-bearing sandstone at the base of the Pennsylvanian. It is first seen on going north from Crofton just north of the main fault, where it is dipping north at a high angle. It disappears to the north beneath a thick bed of Pennsylvanian shales. Just north of the last or third fault the same pebble-bearing sandstone appears again in the high hill along the Crofton and Empire wagon road one-half mile south of Empire station. Its presence at the two places one mile apart can be explained either by an overturned fold or by one or more block faults as shown in Fig. 2. The block faulting seems to accord with the facts as exemplified in the rock exposures. The folds, as shown in Figures 1 and 2, are the result of the lateral pressure attending the faulting, assisted by the dropping of the blocks on the south, catching and pulling down the edges of the rocks on the north side of the fault.

A large amount of erosion has taken place since the development of these faults, but there is a well-marked escarpment along the fault zone where the pebble-bearing sandstone, at the base of the Pennsylvanian, comes to the surface. It is traceable from the high ridge, 1 mile north of Crofton, in a direction of about N. 75 degrees east to West Fork of Pond River. From here to Pond River the effects of the faults at the surface are not so well marked. From Pond River to the eastern edge of the quadrangle a fault having a bearing of about N. 85 degrees east brings the Mannington coal down 100 feet above the base of the Pennsylvanian rocks. West of Sharber's store what is probably the same fault, with a slight change in direction, shows in the road just south of Atkinson school house, and again just north of McFarland Creek in the neighborhood road, ¾ mile to the east. This fault apparently fades out to the west and its complement is the Crofton and Apex faults.

THOMAS STORE FAULT: Two and a half miles south of Crofton a fault having a general bearing of N. 87 degrees east is discernible on the old and new lines of the Louisville & Nashville Railroad and on the Hopkinsville pike. Between the old and new lines of the railroad and for some distance to the east the fault forms a sandstone escarpment on the south abutting the Chester limestone on the north. In the region of Crofton there is a level valley between Thomas store fault and the main Crofton fault.

The north side of the Thomas store fault is the downthrow side. One hundred feet south of the main fault is an adjustment fault, with only a slight displacement, with the downthrow on the south. The rocks in the fault plane are standing at an angle of 70 degrees. Another small adjustment fault occurs ¼ mile south of the main fault. The dip of the rocks between these faults is to the south.

The Thomas store fault apparently fades out or is separated into smaller faults east of West Fork of Pond River. The region south of the outcrop of the Pennsylvanian rocks in this quadrangle was not studied in detail. It is known, however, that the country for some distance south of the southern limit of the Nortonville quadrangle is traversed by east-west faults, most of which are of small displacement.

NORTONVILLE FAULT ZONE: The second zone of faulting occurs in the northern third of the quadrangle. The zone is about one mile wide where it enters the quadrangle from the west on the headwaters of Pleasant Run. It has an east-northeast direction and leaves the quadrangle at the northeast corner of the sheet. The faulted zone in the western half of the quadrangle contains three approximately parallel faults with a general direction of about N. 78 degrees east. Between these three main faults are smaller faults which do not show on the surface and whose existence is determined only in mine workings.

NORTONVILLE FAULT: The Nortonville fault is the largest of the three faults of the northern zone. It has a general direction of north 82 degrees east, although readings at different points may vary as much as ten degrees from its general course. This fault was definitely located in Nortonville, where it was encountered in the south entry of the Nortonville Coal Company's mine, 700 feet south of the shaft. It shows at the surface two miles west of Nortonville and again on the crest of the

hill just north of Daniel Boone, 3 miles west of Nortonville. One mile east of Nortonville it was located within a few feet by test holes put down to No. 9 coal. Between Drakes Creek and Pond River the presence of the southernmost fault is known only by test holes, which were put down in an effort to locate the area underlain by No. 9 coal. It is known, however, that somewhere in the region between Nortonville and White Plains the direction of the fault is slightly deflected to the north and it is probably connected with the south fault at Graham.

ST. CHARLES FAULT: The St. Charles or middle fault at Nortonville is almost parallel to the Nortonville fault and about 1,500 feet north of it. Its presence was not suspected until the fault was encountered in driving the north entry in the Nortonville mine. It has been located by bore holes northeast of Nortonville and is well exposed in the Madisonville road on top of the hill just east of Drakes Creek. It unites with the Nortonville fault ½ mile southwest of Concord school house. The westward extension of this fault is traceable for some distance in the Dawson Springs quadrangle.

The area between the Nortonville and St. Charles faults is a down-faulted block.

The amount of displacement in the St. Charles fault in the coal mine at Nortonville is 119 feet with the downthrow on the south. In driving the north entry on No. 11 coal in the mine at Nortonville the fault was encountered at a distance of 800 feet north of the shaft. A core drill hole revealed the presence of No. 9 coal north of the fault 39 feet above the level of No. 11 coal south of the fault, giving a total displacement at this point of 119 feet.

OAK HILL FAULT: A fault which does not disturb the level of the No. 9 coal in the Dawson Springs quadrangle, but seems to have developed entirely within the area of the Nortonville quadrangle, passes just south of Oak Hill, and is known here by that name. The eastward extension of this fault is discernible in the Madisonville road east of Oak Hill. It unites with the Nortonville-Graham faults about one mile east of Pond River. The general direction of this fault is north 81 degrees east.

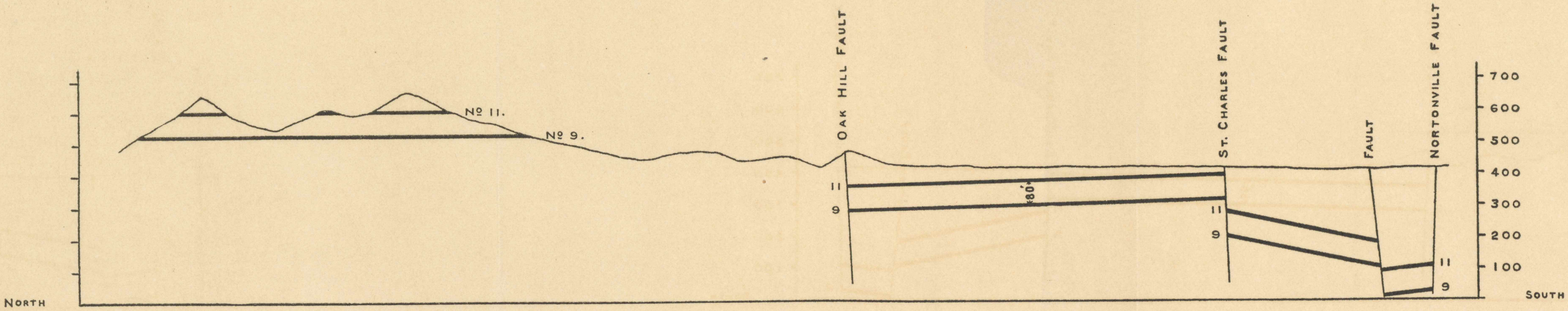

Fig. 3.

Series of faults affecting Nos. 9 and 11 coals between Nortonville and Oak Hill. Horizontal Scale—4 inches=1 mile.

The elevation of No. 9 coal in the high hill just west of Oak Hill is 525 feet above sea level. No. 11 coal, on the south side of the Oak Hill fault at the old No. 2 mine, half way between Nortonville and Oak Hill, is at an elevation of 395 feet. With a distance of 80 feet between Nos. 9 and 11 coals the amount of displacement of the fault in the vicinity of Oak Hill is, therefore, 210 feet. The downthrow is on the south. In the Concord hills, 2 miles north of White Plains, the amount of displacement in the same fault, as determined by bore holes to No. 9 coal, is only 50 feet. The eastward plunge of the axis west of Oak Hill is so great that the fault fades out before reaching the western boundary of the Nortonville quadrangle. A westward extension of this fault would pass a short distance north of St. Charles, where there was no evidence of the fault in working out No. 9 coal. On the other hand, the Dozier Hill fault, which was well developed on the Dawson Springs quadrangle, if extended, would pass ½ mile north of Oak Hill, but it also faded out before reaching the western edge of the Nortonville quadrangle.

Some idea of how rapidly these faults may develop and fade out may be obtained by a study of the faults in the coal mine at Nortonville, where No. 11 coal is worked by shaft 207 feet deep. (Fig. 3.)

In the block in which the Nortonville mine is located the 2d east heading is rising to the east at a ten per cent. grade. In the 1st east heading, 200 feet south, the coal is dipping east at about five per cent. grade. At the end of the two headings in June, 1914, the coal in the 2nd east heading was about 100 feet higher than the same coal in the 1st east heading. These conditions are caused by an east-west fault between the two headings. The presence of the fault was not suspected when work was begun on these east headings, but within a distance of something like 1,000 feet a fault with a displacement of 100 feet was developed. It is now contemplated to tap No. 9 coal, which occurs 80 feet below No. 11, and work out the block north of the fault through the 1st east heading.

NORTON SCHOOL FAULT: The Norton School fault, which is about ¾ mile south and parallel to the

Nortonville fault, on passing eastward from the eastern edge of the Dawson Springs sheet, soon loses its identity as a fault and merges into a low fold. The last evidence to the east is seen in the sand cut just south of the Nortonville lake, where the rocks dip north and south from a small anticline.

GRAHAM FAULTS: A down-faulted block, as shown on the map accompanying this report, has been encountered in driving the south entries of the Graham mines. The mines were opened on the No. 9 coal a short distance north of the north fault. The south fault is about parallel to and a short distance south of the north fault. In driving the 5th east entry No. 11 coal, which in this region is 70 feet above No. 9, was found faulted down on a level with No. 9 coal. The amount of displacement in the north fault diminished to the northeast and disappears entirely a short distance beyond the northern boundary of the Nortonville quadrangle. The amount of displacement in the south fault, near the northeastern corner of the quadrangle, is about 100 feet. Just west of the railroad track, ½ mile south of Graham, No. 11 coal, north of the south fault, has been faulted down to about the level of No. 8 coal, making about 150 feet displacement.

MINOR FAULTS: Other faults which could not be traced for any great distance, and whose influence upon the topography and stratigraphy is of minor importance, were observed at different localities over the quadrangle. In most instances the general direction of the faults is east and west or slightly north of east and south of west. In a few cases, however, cross faults at more or less right angles to the main faults were observed.

DIP.

Between the Crofton and the Nortonville Fault zones the dip of the rocks varies. From the Empire mine, one mile north of Empire, to Mannington, a distance of 2 miles, the northward dip, as shown by the elevation of the coal at these places, is only 50 feet. From Mannington to Crab Orchard Creek, a distance of 1½ miles, the dip is 40 feet. From this point to the lake,

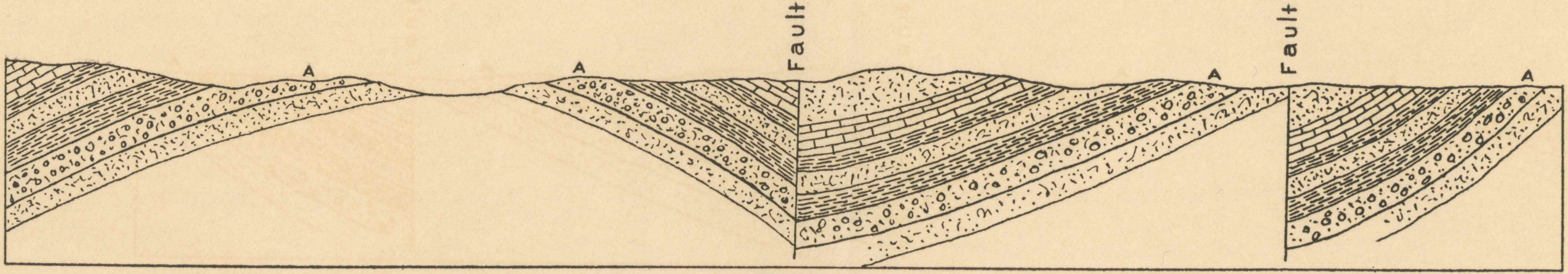

Fig. 2.

Showing how a fold and a series of faults may give rise to the repetition of strata at the surface.

1 mile south of Nortonville, the dip is to the south. From there north to the Nortonville fault the dip is to the north, making an anticlinal fold with its axis crossing near the lake.

From Flat Creek, north of Mortons Gap to the Oak Hill fault the dip, as shown by No. 9 coal, is slightly to the south. From Graham to Pond River, north of the fault zone, the dip of the coal is slightly south of west and is due to the westward plunging of the axis of the Graham fault. The normal dip of the rocks is north. At many points along the faults there is a dip approximately at right angles to the main dip, due to the plunging of the axes of the faults. In the faulted blocks at Nortonville the axes of the faults plunge eastward and give an eastward dip to the rocks.

Influence of faults and dips in the Nortonville quadrangle: The combined influence of faults and dips in the Nortonville quadrangle is to bring to the surface a succession of younger rocks from south to north. The top of the Mississippian rocks, 1 mile north of Crofton, is at an elevation of 620 feet above sea level. In the faulted block at Nortonville, 9 miles to the north, the elevation of No. 9 coal is 163 feet above sea level. The normal vertical distance from the top of the Mississippian to No. 9 coal in this region is approximately 900 feet. The combined dip, from a point 1 mile north of Crofton to Nortonville, is, therefore, 150 feet to the mile, but just how much of this variation should be attributed to faulting and how much to the normal dip can only be approximated.

At the old Empire mine the elevation of the Empire coal is approximately 520 feet above sea level, or 100 feet below the top of the Mississippian rocks. The vertical distance from the top of the Mississippian up to the Empire coal is approximately 467 feet. Therefore, the sum of 467 feet plus 100 feet gives the amount of displacement between the Crofton fault and the southern outcrop of the Empire or Mannington coal.

In the faulted block at Nortonville No. 9 coal is at an elevation of 163 feet above sea level. The vertical distance down to the Mannington coal in the same block is about 475 feet. If the limestone which occurs 40 feet

above the Franklin coal, 2 miles west of Nortonville, is the limestone which occurs 40 feet above the Mannington coal, then the amount of displacement in the Nortonville fault is about 905 feet. In verification of the above it may be stated that the elevation of the Mannington or Empire coal at Crab Orchard Creek, 2½ miles south of Nortonville, is at an elevation of about 400 feet above sea level, and the dip from the Nortonville lake, 1 mile south of Nortonville lake, to Crab Orchard Creek is to the south.

GEOLOGIC HISTORY.

PALEOZOIC ERA.

During the Paleozoric era Western Kentucky was subjected to intermittent submergence in an epicontinental sea which extended well over the Central Mississippi valley. The wide variation in the character of the sediments, which consist of almost pure calcium carbonate, shale and sandstone, indicates a complete change from deep clear waters to an extremely shallow sea. Where conditions were favorable numerous forms of animal life thronged the seas and left their remains in the limestones and shales which were then accumulating.

Since the close of Paleozoic time the region embraced in the Western Kentucky coal field has been a land surface which has been continuously subjected to stream erosion.

CARBONIFEROUS PERIOD.

MISSISSIPPIAN EPOCH.

A large part of the Mississippi Valley was submerged during Mississippian epoch. During Kinderhook and O'Sage epochs sand, limestone and shales were accumulating, while the succeeding Meremac and St. Genevieve epochs show a deep clear sea, in which thick deposits of limestone only were formed. Following the close of the Meremac there was another shifting and warping of the land surfaces and an interval of time during which the area was above sea level and the surface subject to erosion, following which and previous to the beginning of the Pennsylvanian time subsidence during which thick deposits of limestone, shale and sandstone belonging to the Chester group were formed.

PENNSYLVANIAN EPOCH.

At the close of the Mississippian epoch there was a widespread uplift over the Mississippi valley and the Mississippian rocks formed a land surface which was subjected to erosion for a long period of time before the deposition of the Pennsylvanian sediments began. This pre-Pennsylvanian interval was followed by a general subsidence during which a large spoon-shaped basin extending from Central Illinois southeastward into Western Kentucky was formed. This basin was probably connected by a narrow strait through southern Kentucky with the Appalachian trough.

Bordering this extensive and constantly deepening basin was higher land from which rapid streams brought immense quantities of coarse material, including a large percentage of quartz pebbles now found in the basal member of the Pennsylvanian series. From the fact that these quartz pebbles are more numerous in the Appalachian basin and gradually become less numerous to the west it is believed that they were derived largely from the northeast and southeast sides of the trough.

Following the deposition of the pebble-bearing basal member of the Pennsylvanian a succession of shales, sandstones and thin limestones were laid down, while at intervals crustal movements of this part of the region ceased for a time and the surface remained flat and near sea level, with extensive marshes that produced a luxuriant growth of varied plant life with resultant thick deposits of vegetable remains which were again submerged, covered with new deposits of sand and mud and later transformed into coal. The extent of some of these bogs, and the uniformity of conditions that prevailed may be shown by the No. 9 coal which extends over an area of 25,000 square miles and varies less than two feet in thickness.

Clay partings of greater or less thickness are common in many coal seams and indicate temporary flooding by waters carrying an accumulation of silt. It is a significant fact that the coal seams of the central interior coal basin have fewer clay partings than in the Appalachian coal field. The latter was doubtless bordered by a more elevated land area with more rapid streams entering the marshes where coal was accumulating.

Marine sediments and marine fossils found in the roof and floor of some coal seams and at different horizons in the Pennsylvanian series indicate a close proximity to the sea. At times the surface was slightly above and at others slightly below sea level.

When viewed as a unit, the region during Pennsylvanian time was gradually subsiding. Each coal seam was formed at or near water level and then buried by later sediments. Occasionally there was a slight local uplift and some of the coals were subjected to slight stream channeling, or perhaps were entirely cut out in certain localities and the hiatus filled with sediments of sand or mud, or possibly, owing to an uneven land surface at the time of deposition, were not originally deposited over the entire surface. In fact, these conditions seemed to have existed in most of the coals of this region except the No. 9 seam, which is remarkably uniform. Such conditions are especially marked in the Mud River and No. 11 coals.

POST-CARBONIFEROUS DEFORMATION.

Subsidence of the land area, which prevailed throughout Pennsylvanian time in the Mississippi valley, was terminated at the close of Pennsylvanian time and a period of reverse movement or uplift was inaugurated.

This period of uplift was begun by a profound orogenic movement, which was attended by the Appalachian uplift in the east and the Ozark and Ouachita uplift in the west.

In Western Kentucky the uplift was manifested in places by folding and a large amount of faulting which developed considerable irregularities in the original deposition of some of the coals. In Central Illinois there was less deformation than to the south and east, but it is thought that the development of the La Salle anticline in Eastern Illinois was contemporaneous with the faulting in Southern Illinois and Western Kentucky.

In Crittenden and Livingston Counties, Kentucky, and in the adjoining counties of Southern Illinois, igneous or molten rocks were forced up from great depths through fissures, and in places were even forced out between horizontal strata and subsequently exposed by erosion.

Many of the faults in Crittenden and Livingston Counties are highly mineralized and contain rich deposits of fluorspar, zinc and galena ores. In Caldwell county a smaller percentage of the faults are mineralized. In approaching the area where the Pennsylvanian formations form the surface rocks the faults become still less mineralized. In the southern part of the Nortonville quadrangle where the faults have Chester rocks on both sides there is scarcely ever a trace of minerals shown.

In the extreme eastern part of Caldwell County and in the Dawson Springs and Nortonville quadrangles the development of many of the large faults was attended with more or less lateral stress. There is a tendency for many of the faults to change in a short distance from a normal fault to a sharp fold or perhaps to a syncline. The result of such a combination of forces is often to develop steep dips and disturb the rocks for some distance without any great vertical displacement. Just what relation there is between the non-mineralized faults and those that have been attended by strong lateral pressure is not perfectly clear. It is a significant fact, however, that in the Dawson Springs and Nortonville quadrangles, where sandstone and shales prevail, and where more or less lateral pressure attended the faulting, there is a lack of mineral deposits in the faults.

MESOZOIC ERA.

The long period of subsidence which prevailed throughout Pennsylvanian time was accompanied by deposition and was an era of land-building. During that time the sediments that accumulated in the Appalachian trough amounted to thousands of feet, while in

the central interior coal field of Western Kentucky, Indiana and Illinois they may be estimated in hundreds of feet.

The sea was permanently banished from the upper Mississippi valley at the beginning of Mesozoic time and the elevated land area which resulted began to suffer stream erosion. It is quite probable that hundreds of feet of strata have been carried away by stream action; and the coal areas, which originally were far more extensive than now, were reduced to their present limits. Irregularities of the surface occasioned by faulting have largely or entirely been obliterated by erosion.

CENOZOIC ERA.

Tertiary Period.

During late Tertiary times this region was probably a part of a vast peneplain (the result of long continued erosion) with its elevation not much above sea level. On the surface of this plain the principal streams were beginning to cut their channels, approximately at least, in the places where they are found today. This Tertiary plain was afterward subjected to gradual uplifting or a series of uplifts, extending probably into Pliocene times, and this uplifting accompanied by a corresponding deeper cutting of the stream channels. During an early period of this down-cutting action there was apparently a time when this uplift ceased and the rivers were flowing in very wide valleys and at an intermediate elevation between the old surface plain and their present depth. This was followed by a renewed rapid uplift with rapidly increased stream action and followed again by either a cessation of uplift or a much decreased rate. During the above mentioned rapid stream action the rivers brought down and deposited over their valleys quantities of water-worn gravel. Renewal of the uplifting action then caused deeper stream cutting, which continued until the principal channels were cut to a depth of more than 100 feet lower than they are at present, cutting through the old gravel beds deposited at higher elevations and leaving benches and terraces of this material still to be seen along the principal streams at an elevation of about 100 feet above the present stream valleys.

Quaternary Period—Pleistocene Epoch.

During the Pleistocene epoch the northern part of the United States was subjected to no less than four distinct invasions of ice, the southern edge of these ice sheets being just about at the northern edge of Kentucky. The melting of these immense glaciers left thick mantles of clay, loam, sand, gravel and boulders picked up by the ice where it had scoured the land surface traversed and dropped when the ice began to melt. Old erosion channels and inequalities of the land surface were obliterated, leaving the surface, over large areas, practically level.

While the ice sheets occupied the northern states it is presumed that stream erosion continued in Western Kentucky though greatly modified. At the breaking up and melting of the ice sheets the streams, flowing from the front of the retreating ice fields, probably carried large quantities of drift ice, which in turn carried rock, sand and gravel. The great amount of water coming from the front of the melting ice fields backed the water and drift ice into the deeply channeled stream beds of Western Kentucky, where quantities of gravel and smaller sediments were deposited, partially refilling the previously deep cut channels.

Recent Epoch.

Following the retreat of the ice sheets, streams in this region have continued to widen their valleys, and their channels have again been somewhat deepened, but in the larger stream valleys there is evidence, from deep drillings, that the streams once flowed in valleys 100 to 120 feet deeper than at present, and these portions of the old channels are still filled with river alluvium, gravel, etc. At present the only action affecting the surface of the region is the constant wearing away of the divides and slopes by weathering agents and the action of surface waters.

ECONOMIC GEOLOGY OF THE COALS.

COALS BELOW No. 9.

MANNINGTON COAL.

The lowest coal worked in the Nortonville quadrangle is the Mannington or Empire coal, which is correlated with the Dawson coal in the Dawson Springs quadrangle. The coal has been worked as a commercial product at a number of places between Empire and Crab Orchard Creek, adjacent to the Louisville & Nashville Railroad. Country mines on the same coal have been opened on Gray's Branch and McFarland Creek, in northern Christian and southern Hopkins Counties. The same coal has been opened one mile north of Long Creek, 1/4 mile west of the eastern boundary of the quadrangle.

The Mannington coal is easily recognized in this region by a thin impure limestone which comes 30 to 45 feet above the coal, as shown in the section at Mannington.

The area of outcrop of the Mannington coal in the Nortonville quadrangle is a belt 1 to 4 miles wide, extending in an east-west direction near the center of the quadrangle. The area of outcrop is wider in the western part where the dip is flatter. East of Pond River the northward dip carries the coal below the surface before reaching Jarrell Creek. It is worked for the local trade at a number of places west of Empire and is traceable through the hills to Dawson Springs and Charleston, where it has been worked for a number of years. East of the Nortonville quadrangle it has been opened in very few places west of Belton. From Belton eastward to Morgantown it thickens up in places and becomes of considerable local importance as a source of fuel.

The Mannington coal has been opened in the branch 1 mile north of Long Creek and 1/4 mile west of the eastern boundary of the Nortonville quadrangle, where it is opened a few feet north of the Sharber's store fault. It is reported to be 4 feet thick, with a thin parting of sulphur or clay near the bottom. It is a free burning coal and said to be excellent shop coal. A thin limestone

occurs in the hill 35 feet above the coal. The elevation of the coal is 465 feet.

Two miles due west of the above mentioned opening, and 1/2 mile east of Emery school house, the thin limestone above the Mannington coal outcrops in the road at an elevation of 440 feet. A six-foot seam of coal is reported in a shallow well at this place.

At Empire the average thickness of the coal is about 36 inches, with individual measurements varying from 32 to 46 inches.

In the Petersburg Coal Company's mine at Mannington the coal has thickened to 4 feet with an average thickness of 44 inches. At the latter place there is a thin clay parting 5½ inches from the bottom of the coal, as shown in the following section. It seems probable that the thin coal, which comes 8 feet below the main coal at the Gibson opening, has here united with the main coal, thereby accounting for the greater thickness here than at Empire.

Section at Mannington.

		Feet.	Inches.
	Hard sandstone	10	
	Aluminous gray shale, weathering red	30	
	Hard coal		4
	Shale		10
	Coal		11
	Blue shale, weathering chocolate	30	
	Shaly sandstone	3	
	Gray shale	18	
	Purple pipe clay, about	2	
	Sandstone, laminated	10	
	Shale	12	
	Limestone, hard blue	3	
	Blue shale	8	
	Sandstone	14	
	Siliceous shale. Just above the coal the shale contains small ferns, reeds and other plant impressions	20	
Mannington Coal.	Coal, soft	0	3½
	Sulphur band	0	0½
	Coal, soft	2	8
	Clay parting, dark	0	0¾
	Coal, soft	0	5½
	Hard fire clay floor.		

The upper part of the Mannington section was obtained from the hill just south of the mine.

At the Gibson bank, ½ mile west of Red Hill, the Mannington coal has been opened for local trade. The elevation of the mouth of the drift is 440 feet above sea level. The coal is 3 feet to 3½ feet in thickness and has a soft shale roof and clay floor. About 8 feet below the base of the coal is a thin coal reported to be 12 inches thick. This thin coal is also reported to be present at other mines on Grays Branch.

At Atkinson school house the thin coal, which occurs 8 feet below at the Gibson opening, has united with the main coal in the Jenny Creek mine with a 4 inch clay parting between. The full thickness of the seam, including the clay parting, is 5 feet 4 inches. The opening is known as the Jenny Creek Mine. The following is a section at that place. Elevation of coal is 500 feet:

Section at Jenny Creek Opening.

	Feet.	Inches.
Hard micaceous sandstone	15	
Covered, perhaps shale	10	
Limestone	2	
Shale, in part siliceous	45	
Coal	4	4
Clay parting		4
Coal		8
Fire clay.		

The Sharber's store fault shows in the road just south of the Jenny Creek Mine and drops the limestone 70 feet lower south of the fault than it is north of the fault.

About half way between Red Hill and Atkinson school house the following section was obtained along the public road:

Section Between Red Hill and Atkinson School.

	Feet.
Limestone	2
Shale and thin sandstone	40
Coal, Mannington	3
Shale with some sandstone	40
Sandstone, heavy bedded	10

One mile west of Red Hill, on the south side of Grays Branch, the Mannington coal has been opened on the Hamby place at an elevation of 420 feet. The thin limestone is present in the hill to the south 40 feet above the coal.

At a point ¾ of a mile north of the Hamby opening, and ¼ mile west of the Red Hill and White Plains road, Mr. S. F. Cates is working a coal that has some of the physical characteristics of the Mannington coal, but the position of the limestone above the coal is entirely different. A comparison of the analyses of the Cates coal and of the Empire and Mannington coals shows a larger amount of sulphur, ash and volatile matter in the Cates coal than in the latter.

The elevation of the Cates coal is 440 feet, or 20 feet higher than the coal at Hamby's bank, ¾ of a mile to the south. If the dip continues from the Hamby opening to the Cates opening as it does from the Jenny Creek opening to the Hamby opening, the Cates coal would be about 44 feet stratigraphically higher than the coal at Hamby's. The following is a section at the Cates mine:

Section at Cates Mine.

	Feet.	Inches.
Limestone, through an interval of	17	
Black slate	2	
Coal	2	4
Shale parting		1
Coal	1	3
Clay floor.		
Sandstone.		

Near the top of the limestone is a light, porous, cellular, fossiliferous horizon, similar to that found north and west of Dawson Springs.

A thin coal without limestone above it is reported in the Empire shaft 37 feet above the main coal worked at that place. The following record of the old Empire shaft is given by L. C. Glenn in Bulletin No. 17, Kentucky Geological Survey, page 59.

Log of Old Empire Shaft.

	Feet.	Inches.
Surface	18	
Coal	2	
Bastard limestone	10	
Slate and sandstone, mixed	27	
Coal (Empire coal)	3	8

In the above record there is a thick limestone 27 feet above the Empire coal, but the thin coal is above the limestone and not below it, as is the case at the Cates mine.

In the first hill south of Crab Orchard Creek on the west side of the Louisville & Nashville Railroad, a coal has been opened beneath a thick limestone. The opening on the coal is now closed, but the thickness of the limestone and the distance between the coal and the limestone suggest the Cates coal rather than the Mannington coal.

Section ½ Mile South of Crab Orchard Creek.

	Feet.
Limestone	10
Shale	12
Coal, Cates (?).	

What is probably the Cates limestone outcrops in the sharp nose between Jarrel Creek and Pond River, ¼ mile west of the westernmost of the Atkinson hills. The elevation of the limestone is 400 feet. The limestone is 10 feet thick. The thin, porous, fossiliferous zone occurs near the top of the limestone, similar to that found at the Cates mine.

The Mannington coal has a reputation of being of superior quality as a steam coal and the analyses shown below justify this claim. Although it averages only about 3½ feet in thickness, it is easily and cheaply mined and has been of considerable importance in this field. The fire clay below is hard, and the shale roof gives very little trouble and stands in 22-foot rooms with little or no timbering.

The quality of the coal in the Empire mine is greatly enhanced by a band of cannel coal 1 to 7 inches thick which occurs near the bottom of the seam. Cannel coal has also been reported in the same seam from an old opening on the headwaters of Grays Branch.

Four samples of coal were collected from the Empire mine on April 4, 1914, and the analyses made by A. C. Fieldner in the laboratory of the U. S. Bureau of Mines. The samples were all cut from the face of the coal by the standard method used by the U. S. Bureau of Mines. Analyses follow:

Analyses of Coal From Empire Mine, ¾ Mile West of Empire.

Location in mine.	Condition.	Moisture	Volatile matter.	Fixed Carbon.	Ash	Sulphur	Calories	British Thermal Units.
Face of main 6th West entry—406 feet from shaft.	As received	11.24	35.77	48.55	4.40	2.12	6789	12220
	Air dried	4.70	38.40	52.13	4.77	2.28	7289	13120
	Moisture free	....	40.30	54.70	5.00	2.39	7648	13766
	Moisture and ash free	....	42.42	57.58	....	2.52	8050	14490
Face of 1st north off 6th west entry—3,500 feet from shaft.	As received	9.59	37.02	47.19	6.20	2.60	6841	12314
	Air dried	4.33	39.17	49.94	6.56	2.75	7239	13030
	Moisture free	....	40.93	52.19	6.86	2.88	7567	13621
	Moisture and ash free	....	43.97	56.03	....	3.09	8125	14625
Face of 8th west off south entry—3,000 feet from shaft.	As received	10.79	35.46	50.67	3.08	1.48	6963	12533
	Air dried	5.39	37.61	53.73	3.27	1.57	7385	13293
	Moisture free	....	39.75	56.80	3.45	1.66	7086	14051
	Moisture and ash free	....	41.17	58.83	....	1.72	8085	14553
Face of main south entry—3,000 feet from shaft.	As received	11.18	34.48	52.70	1.64	0.84	7056	12701
	Air dried	4.95	36.90	56.40	1.75	0.90	7551	13592
	Moisture free	....	38.82	59.33	1.85	0.95	7944	14299
	Moisture and ash free	....	39.55	60.45	....	0.97	8093	14567

Composite of Above Four Analyses.

		As received.	Air dried.	Moisture free.	Moisture and ash free.
Proximate analysis	Moisture	10.79	4.93		
	Volatile matter	35.72	38.07	40.04	41.83
	Fixed Carbon	49.68	52.94	35.69	58.17
	Ash	3.81	4.06	4.27	
		100.00	100.00	100.00	100.00
Ultimate analysis	Hydrogen	5.85	5.51	5.21	5.44
	Carbon	70.02	74.62	78.49	81.99
	Nitrogen	1.65	1.76	1.85	1.93
	Oxygen	16.92	12.19	8.22	8.59
	Sulphur	1.75	1.86	1.96	2.05
	Ash	3.81	4.06	4.27	....
		100.00	100.00	100.00	100.00
	Calories	6898	7351	7733	8078
	British thermal units	12416	13232	13919	14540

One sample of coal from the Mannington mine was collected in the same manner as those from the Empire mine and placed in a bucket with a tight-fitting lid, but not air tight. The analysis was made in the laboratory of the Kentucky Geological Survey by J. S. McHargue:

Analysis of Coal From Petersburg Coal Co.'s Mine at Mannington.

Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	British thermal units.
As received	8.88	38.08	47.43	5.61	2.38	12875
Air dried	3.37	40.38	50.30	5.95	2.52	13652

Analysis of Coal From S. F. Cates' Mine, Three Miles South of White Plains.

Condition.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	British thermal units.
As received	7.23	41.79	44.93	6.05	4.04	13250
Air dried	2.65	43.85	47.15	6.35	4.24	13902

White Plains Coal.

Several years ago a number of test holes were put down in the vicinity of White Plains with a view of locating a coal that could be worked on a commercial basis. A drill hole was put down ½ mile west of town and a coal found at a depth of about 193 feet which was thought to be No. 11. A shaft was sunk nearby to the coal, but it did not prove to be No. 11 coal and the work was abandoned. In the summer of 1914 the water was pumped out of the shaft and work was resumed. The following log of the test hole which was put down near the shaft was furnished by L. E. Littlepage. Elevation of surface 465 feet.

Log of Test Hole at White Plains.

	Feet.	Inches.
Surface	5	6
Gray sandstone	13	
Shale	23	6
Slate and rotten coal	2	
Blue sandstone	13	
Gray slate	10	
Shale	10	
Soft, blue sandstone	13	
Shale	8	
White sandstone	39	
Gray slate	22	
Hard limestone	4	6
Gray slate	29	
Black slate	0	6
Coal	1	4
Clay parting	0	8
Coal	2	4
Clay parting	0	4
Coal	1	1
Bone coal	0	¾
Hard fire clay	2	
Sandy shale	11	
Sandstone	52	
Gray slate	25	6
White sandstone	3	
Blue shale	4	3½
Coal	0	5
Fire clay	1	
Gray shale	11	7
Gray slate	26	
Fire clay	2	
Hard rock (sandstone?)	9	
Hard sandy shale	4	
Gray slate	19	
White sandstone	2	5
Total	372	¼

The clay partings in the coal contain thin knife-blade thicknesses of coal.

The coal is a medium hard block coal with more or less mother of coal partings. It is a free burning coal and is said to be suitable for welding.

The White Plains coal, with its two thick clay partings, is unlike any other coal in the district. The limestone 30 feet above it would indicate the Mannington coal, but the physical character of the coal differs widely from it.

TERRY SPRING COAL.

Two miles northeast of White Plains Mr. C. B. Dillingham has opened a coal close under a heavy bedded cliff-forming sandstone. The elevation of the coal is 420 feet above sea level. The following is a section at the mouth of the opening:

Section at Terry Spring.

	Feet.	Inches.
Coarse, cliff-forming sandstone	45	
Shale	12	
Rotten limestone		7
Coal	1	4
Sulphur parting		1
Coal	1	3
Fire clay	1	6
Limestone	8	6
Section continued by test hole:		
Shale	8	
Gray sandstone	21	
Gray shale	25	
Black shale	4	
Coal	1	
Fire clay	2	
Gray shale	10	

The test hole was stopped on top of a hard rock which the drill would not penetrate.

The Terry Spring coal has been opened just south of the railroad bridge at Bakersport at an elevation of 440 feet, or 20 feet higher than at Terry Spring. The following section was made at the mouth of the opening:

Section at Bakersport.

	Feet.
Cliff-forming sandstone.	
Coal	3
Limestone	8

The shale between the sandstone and the coal has been cut out and the coal lies immediately below the sandstone.

A test well, 1¼ miles northeast of White Plains, was drilled to a depth of 266 feet without penetrating any coal of sufficient thickness to justify operation at present. The log of the well was furnished by the St. Bernard Mining Company and shows the following strata penetrated:

Log of Test Hole 1¼ Miles Northeast of White Plains.

Elevation of surface about 400 feet.

	Feet.	Inches.
Clay	15	
Soapstone	17	6
Limestone	0	6
Black slate	2	10
Coal	0	2
Sandstone	10	
Shale	5	
Sandstone	14	
Shale	17	6
Coal	0	6
Fire clay	1	
Limestone	2	6
Gob	1	
Coal	3	6
Fire clay	5	
Sandstone	9	
Shale	3	
Limestone	5	
Shale	32	
Sandstone	60	
Limestone	1	
Shale	8	
Sandstone	20	
Shale	6	
Sandstone	26	
Total	266	

FRANKLIN COAL.

A thick coal has been opened in two places on Bailey Franklin's place, 2 miles west of Nortonville. The openings are about ¼ mile south of Pleasant Run Creek, and just south of the Nortonville fault. This coal is somewhat of a puzzle as it is in the same faulted block in which the No. 11 coal is worked at Daniel Boone, 1 mile to the west. At the latter place No. 11 coal at the tipple is 30 feet below the surface, and less than ½ mile to the east a strong eastward dip has carried it down 120 feet below the surface. Should this dip continue eastward to the Bailey Franklin opening, No. 11 coal would there be about 475 feet below the surface. Just south of Nortonville deep borings in the Daniel Boone block have failed to show any trace of No. 11 coal. In fact, the rocks east of Franklin's and south of the Nortonville fault, all have the appearance of strata below No. 9 coal. To explain the presence of No. 11 coal at Daniel Boone, and strata below No. 9 coal at Bailey Franklin's, there must be a north-south fault between the Norton School fault and the Nortonville fault, near the western boundary of the Nortonville quadrangle. The strata west of the north-south cross-fault have dropped 350 or 400 feet. East of the cross-fault the Norton School fault gradually fades out and merges into a low fold, as shown at the lake 1 mile south of Nortonville. East of the cross-fault the Nortonville fault plunges rapidly eastward to Nortonville and beyond.

In view of the above conditions it is readily understood how a coal, which belongs 200 feet or more below No. 9 coal, may appear at the surface at Bailey Franklin's. The excessive thickness of the Franklin coal is due to a local thickening, or, what is more probable, two coals have come together in this locality. The thin clay parting, as shown in the section below, would suggest such an explanation:

Section at Bailey Franklin's Opening.

	Feet.	Inches.
Limestone	2	
Shale	10	
Coarse grained sandstone	7	
Shale	3	
Coal		10
Shale	6	8
Coal, upper bench	5	
Clay parting		2
Coal, lower bench	5	

The same coal has been opened 1/4 mile west of the present Franklin opening. Between the two openings and to within 1/2 mile of Daniel Boone, the limestone, shown in the above section, outcrops on both sides of the east-west ridge. The limestone is in two or more ledges, extending through a vertical interval of 15 feet. A thin coal is reported as occurring just above the limestone, but it was not seen by the writer.

The limestone, from 1/2 mile east of Daniel Boone to within 1/4 mile of the Nortonville lake, shows an eastward dip at the rate of about 15 feet to the mile.

No. 9 COAL.

No. 9 coal underlies the area included between the Nortonville and the Oak Hill faults west of Pond River and in the triangular faulted block extending as far north as Long Pond. In the Nortonville block at Nortonville it is 287 feet below the surface. It rises rapidly to the west. A short distance west of Daniel Boone, which is 3 miles west of Nortonville, No. 8 coal outcrops at the surface in the Nortonville block. East of Nortonville the eastward dip continues for some distance and then reverses. The eastward rise is not sufficient, however, to bring the No. 9 or even the No. 11 coal to the surface east of Nortonville in the Nortonville block.

In the faulted block between St. Charles and Oak Hill faults No. 9 coal is from 100 to 200 feet below the 400-foot contour line. It is lowest along the southern boundary adjacent to the St. Charles fault. At a point half way between Nortonville and Oak Hill it is only 100 feet below the surface The difference in elevation is doubtless due to one or more east-west faults with the downthrow on the south.

West of the Louisville & Nashville Railroad, in the block between the St. Charles and the Oak Hill faults, a rapid westward rise brings No. 9 coal to the surface before reaching the western boundary of the quadrangle. One mile west of the western border, on the west side of Pleasant Run, No. 9 coal outcrops in the hills at an elevation of 520 feet above sea level. A short distance west of the Madisonville road and 1¾ miles northeast of Nortonville, in the same down-faulted block, No. 11 coal is reported at an elevation of about 270 feet. No. 9 coal 80 feet lower would be at an elevation of 190 feet above sea level, showing a continuation of the strong eastward dip.

At Concord school house No. 9 coal, as shown in the following log furnished by the St. Bernard Mining Company, is at an elevation of 220 feet above sea level:

Log of Concord Well.

Elevation of surface about 550 feet A. T.

	Feet.	Inches.
Soil and clay	4	
Sandstone	35	
Soapstone	1	6
Brown hard rock	0	6
Shale	34	
Sandstone shale	109	
Shale	5	
Coal	1	6
Fire clay	7	6
Limestone and sandstone	15	
Shale	24	
Coal, No. 12	6	
Limestone	4	6
Coal, No. 11	6	6
Fire clay	3	
Shale	8	
Sandstone	15	
Shale	44	
Black slate	2	
Coal, No. 9	4	
Total	330	

On top of the hill just west of the cemetery at Concord Church a fault, with a bearing of N. 17 degrees east, has a displacement of 30 feet. The downthrow is on the west side.

A triangular block lying north of the Oak Hill fault, west of Pond River and east of the Concord fault, is underlain by No. 9 and No. 11 coals. The presence of these coals in this area is based on the information contained in the H. B. Lacy test hole which is 1 mile north of Concord school house on the White Plains and Long Pond road. The log was furnished by the St. Bernard Mining Company. The elevation of the top of the well is approximately 450 feet.

Log of Lacy Well.

	Feet.	Inches.
Soil and clay	10	
Sandstone	33	
Shale	11	
Coal	1	6
Clay	3	6
Sandstone	16	
Shale	34	
Coal, No. 12	5	
Fire clay	1	
Limestone	1	6
Black shale	0	6
Coal, No. 11	6	
Fire clay	5	
Sandstone	7	
Shale	5	
Sandstone	23	
Shale	32	
Black slate	3	
Coal, No. 9	5	
Total	203	

The elevation above sea level of No. 9 coal in the Lacy well is 247 feet, or 27 feet higher than at the Concord well.

No. 9 coal in the area west of Drakes Creek and north of the Oak Hill fault occurs as outliers in all of the hills which rise to an elevation of 500 feet or more.

The elevation of the coal varies from 480 feet, along the northern boundary of the quadrangle, to 525 feet just north of the Oak Hill fault. The numerous small outliers indicate that the No. 9 coal was originally a continuous coal bed throughout this region, but has gradually been reduced to its present limited extent by stream erosion.

The presence of No. 9 coal in the region between Oak Hill and Nortonville is entirely the result of downthrow block faulting which has preserved the coal from erosion.

East of Pond River No. 9 coal underlies the ridge from Pond River to Graham and beyond. It outcrops on the north side of the ridge at an elevation varying from 400 feet near Pond River to 460 feet 1½ miles west of Graham. At Graham, and in the first branch to the west, the elevation of the coal is approximately 460 feet. It is limited on the south by the South Graham fault.

The average interval between No. 9 and No. 11 coals in the northwestern part of the Nortonville quadrangle is 80 feet. In the Concord and Lacy wells the interval is 72 and 75 feet, respectively. In the region of Graham the interval varies from 60 to 70 feet.

No. 9 coal, where present in the Nortonville quadrangle, is characterized by its uniform thickness, freedom from regular partings, and invariably has a black slate roof which renders the coal easy of determination. No. 8 coal has a black slate roof similar, in many respects, to the roof of No. 9 coal, but No. 8 coal rarely exceeds 18 inches in thickness, whereas the thickness of No. 9 coal is never below 4 feet and in some localities attains a thickness of 5 feet 8 inches. The roof of No. 9 stands well with a small amount of timbering, but in main haulage ways, where a mine is operated for years, the roof should be securely propped by cross timbers. The floor is a medium to hard fire clay, which does not creep readily.

The mining of No. 9 coal in Western Kentucky is attended with fewer troubles than any other coal in the region. While it rarely attains the thickness of No. 11, the absence of dirt slips and clay partings, and the uni-

formity in thickness of the coal make it the most desirable mining proposition in Western Kentucky.

From two to eight samples of No. 9 coal were collected from 17 different mines in Western Kentucky and the coals analyzed in the laboratories of the U. S. Bureau of Mines. The following is a general average of volatile matter, fixed carbon, ash, sulphur and British thermal units of moisture free coal:

Composite of Analyses of No. 9 Coal in Western Kentucky.

Volatile matter	40.44
Fixed carbon	48.83
Ash	10.71
Sulphur	3.76
B. t. u. (air dried sample)	12865.

No. 9 coal is worked just north of the St. Charles fault in the Nortonville mine at an elevation of 282 feet above sea level. The fault at this place has thrown No. 11 coal on the south side 39 feet below No. 9 coal on the north of the fault. An incline has been built from the level of No. 11 coal south of the fault, up to the level of No. 9 north of the fault. The coal at the No. 9 level is mined and let down the incline to the No. 11 level and the coal from both veins elevated through the same shaft.

In the first high hill west of Oak Hill No. 9 coal occurs at an elevation of 525 feet above sea level. The coal has been worked out of this hill and the mine abandoned. The following is a section at the mouth of the old mine:

Section in Hill West of Oak Hill.

	Feet.	Inches.
Shale.		
Black slate	3	
Coal, No. 9	5	6
Fire clay.		
Shale	60	

DICK FERGUSON MINE.

No. 9 coal is worked in the second hill, 1 mile west of Oak Hill station. The elevation of the coal is 515 feet. The following section was measured at the mouth of the mine:

Section at Mouth of Dick Ferguson Mine.

	Feet.	Inches.
Shale.		
Black slate	3	
Coal, No. 9	5	
Fire clay	1	6

At a point 1 mile northwest of the Dick Ferguson opening a country bank is opened on No. 9 coal at elevation of 510 feet. The coal at the mouth of the opening is 5½ feet thick.

On the southern point of the ridge, 1½ miles due south of Mortons Gap, on the west side of the Louisville & Nashville Railroad, No. 9 coal outcrops at an elevation of 515 feet. The coal from the eastern part of this ridge has been worked out through the opening of the Diamond mine.

DIAMOND MINE.

The Diamond mine, whose main office is at Mortons Gap, is opened by drift on No. 9 coal at a point ½ mile south of Mortons Gap. The coal from the high ridge extending westward from Mortons Gap for a distance of 2 miles is being taken out through the Diamond opening. The St. Bernard Mining Company, which owns the coal rights between Mortons Gap and Fox Run mine, 4 miles south of west of Mortons Gap, is extending the main west entry from the Diamond mine to eventually connect with the main east entry from the Fox Run mine and the coal from the region between the two mines will be taken out by motor haulage through the two openings. The thickness of No. 9 coal in this ridge, as shown from a number of measured sections, varies from 4 feet 7 inches to a little more than 5 feet.

No. 9 coal has been worked out of the ridge east of the railroad between Mortons Gap and Oak Hill. The coal at the old opening on the south end of the ridge just north of Oak Hill is at an elevation of 525 feet.

In the hills between the Madisonville and White Plains road and Drakes Creek, on what is known as the "military tract of land," No. 9 coal is practically untouched. Along the southern border of the "military

tract'' No. 9 coal is at an elevation of about 500 feet above sea level and drops to 480 feet at the northern border of the quadrangle.

GRAHAM MINES.

Two openings are made on No. 9 coal at Graham. The one on the west is known as the Graham and the one east of the branch the Skibo opening. These two mines are operated by the W. G. Duncan Coal Company, and have a combined daily output of 2,000 tons. Both mines use the same tipple in loading coal into railroad cars. The Graham opening enters the coal by drift and the Skibo by slope. The thickness of the coal in the two mines varies from 4 feet 6 inches to 5 feet 6 inches, with an average of 5 feet 2 inches. The elevation of the coal is approximately 450 feet.

In driving the south entries of these mines a fault was encountered a short distance south of the tipple with a bearing of N. 61 degrees east. In one of the entries working No. 9 coal the fault was crossed and the entry was driven for some distance on No. 11 coal. No. 11 coal had been faulted down from its normal position of 70 feet above No. 9 on a level with it. In the next entry to the west No. 11 on the south side was 10 feet below the level of No. 9. East of Graham the amount of displacement becomes gradually less and the two coals assume their normal position a short distance northeast of the northeast corner of the Nortonville quadrangle.

COALS ABOVE No. 9.

No. 11 COAL.

Next to No. 9 coal, No. 11 is the most extensively mined coal in Western Kentucky. In the Nortonville quadrangle, however, the operations on this coal are confined to the two down-faulted blocks in the region of Nortonville. At the latter place the blocks in which it occurs have been faulted to a sufficient depth below the surface to give the coal a good cover. North of these down-faulted blocks it barely catches under the tops of the highest hills west of Drakes Creek and efforts to

work it have sooner or later been abandoned owing to lack of cover. East of Pond River it is present in the high east-west ridge which extends from Pond River to Graham. Here, as in the hills around Mortons Gap, it is too near the top of the ridge to be worked in competition with No. 9 coal. Its southern area, east of Pond River, is limited by the South Graham fault.

North of the Nortonville quadrangle the strong northward dip carries No. 11 coal below the general surface level and it is extensively worked at Earlington and Madisonville. In the hills south of the Nortonville and Graham faults all traces of it have been removed by erosion.

In the Nortonville quadrangle No. 11 coal occurs 60 to 80 feet above No. 9 coal, and 4 to 8 feet below the No. 12 seam. The interval between No. 11 and No. 12 consists of a hard limestone just beneath No. 12 coal, and 18 inches to 3 feet of shale and black slate between the limestone and the top of No. 11 coal. In places the black slate thickens to 2 to 3 feet and greatly resembles the black slate above No. 9. In some localities the black slate is absent and the soft shale or ''gob'' forms a treacherous roof to the coal. If the gob is all taken down to the overlying limestone the latter will stand in the rooms indefinitely without timbering. A hard fire clay forms the floor of the coal.

No. 11 seam is a medium hard, bituminous coal varying from 5 to 7 feet in thickness. It is separated into three benches by a thin band of sulphur 16 to 18 inches from the top and a 2-inch clay parting, known as the ''blue band,'' 24 to 26 inches from the bottom. The upper bench is the best in quality and is known as shop or gas coal. It is a jet black, brittle coal practically free of sulphur and low in ash. The middle bench, while inferior to the upper bench, is a good hard coal with an occasional sulphur lens or mother of coal parting. The lower bench is of poorer quality and runs high in sulphur and ash.

The overlying limestone, and the persistent ''blue band,'' which is always present in No. 11 coal, serve as characteristic marks in identifying this coal.

NORTONVILLE MINE.

The Norton Coal Mining Company at Nortonville is working No. 11 coal by shaft at a depth of 207 feet below the surface. The presence of No. 11 coal here is due to a down-faulted block which is limited by the Nortonville fault, 700 feet south of the shaft, and the St. Charles fault, 800 feet north of the shaft.

In driving the main north entry the coal was suddenly cut off when the St. Charles fault was encountered. By means of a test hole, which was drilled from the surface north of the fault, No. 9 coal was located 39 feet above the level of No. 11 coal in the Nortonville mine. An incline was constructed from No. 11 up to the No. 9 level and the two coals are now being mined and hoisted from the same shaft. The faulting in this mine was more fully discussed on a previous page.

Six samples of No. 11 coal were collected from the Nortonville mine and the analyses made by A. C. Fieldner in the chemical laboratory of the U. S. Bureau of Mines, at Pittsburgh. The samples were all cut from the face of the coal by the standard method employed by the U. S. Bureau of Mines. Measurements were made at the face of the coal where each sample was taken. The following is a fair average section of the coal as it appears at the face:

Section in No. 11 Coal, Nortonville Mine.

	Feet.	Inches.
Coal, clean	1	3
Sulphur parting	0	1
Coal, clean	1	1
Mother coal, not everywhere present	0	1
Coal streaked with mother coal and sulphur	1	8½
Blue band, clay parting	0	2
Coal containing mother coal and sulphur	2	0
Total	6	4½

Analyses of No. 11 Coal from Norton Coal Mining Company's Mine, Nortonville.

Location in mine.	Condition.	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Calories	British Thermal Units.
Face of 23d room, No. 1 west back heading—2500 feet from shaft.	As received	7.38	39.42	45.90	7.30	3.68	6819	12274
	Air dried	3.90	40.90	47.63	7.57	3.82	7075	12735
	Moisture free		42.56	49.56	7.88	3.97	7362	13252
	Moisture and ash free		46.20	53.80		4.31	7991	14384
Face of 27th room, 2d east entry—2500 feet from shaft.	As received	8.36	38.36	46.28	7.00	3.30	6782	12208
	Air dried	4.03	40.17	48.47	7.33	3.46	7102	12784
	Moisture free		41.86	50.50	7.64	3.60	7401	13322
	Moisture and ash free		45.32	54.68		3.90	8013	14423
Face of 23d room, 2d west entry— 3000 feet from shaft.	As received	7.59	37.98	46.52	7.91	3.90	6728	12110
	Air dried	3.74	39.56	48.46	8.24	4.06	7008	12614
	Moisture free		41.10	50.34	8.56	4.22	7280	13104
	Moisture and ash free		44.95	55.05		4.61	7961	14330
Face of 2d east entry air course —3000 feet from shaft.	As received	7.67	39.13	46.71	6.49	3.41	6878	12380
	Air dried	3.51	40.89	48.82	6.78	3.56	7188	12938
	Moisture free		42.38	50.59	7.03	3.69	7450	13410
	Moisture and ash free		45.58	54.42		3.97	8013	14423
Face of 25th room off 1st west entry—2500 feet from shaft.	As received	7.92	39.22	46.79	6.07	3.10	6886	12395
	Air dried	4.54	40.66	48.51	6.29	3.21	7139	12850
	Moisture free		42.59	50.82	6.59	3.37	7478	13460
	Moisture and ash free		45.59	54.41		3.61	8005	14409
Face of 2d west entry—3000 feet from shaft.	As received	7.83	38.64	46.92	6.61	3.48	6843	12317
	Air dried	4.61	39.99	48.56	6.84	3.60	7082	12748
	Moisture free		41.92	50.91	7.17	3.78	7425	13365
	Moisture and ash free		45.16	54.84		4.07	7998	14396

Composite of Above Six Analyses.

		As Received	Air Dried	Moisture Free	Moisture and Ash Free
Proximate analysis	Moisture	7.87	4.14		
	Volatile matter	38.89	40.46	42.21	45.67
	Fixed carbon	46.27	48.15	50.22	54.33
	Ash	6.97	7.25	7.57	
		100.00	100.00	100.00	100.00
Ultimate analysis	Hydrogen	5.54	5.32	5.07	5.49
	Carbon	68.51	71.28	74.36	80.45
	Nitrogen	1.25	1.30	1.36	1.47
	Oxygen	14.19	11.17	7.80	8.44
	Sulphur	3.54	3.68	3.84	4.15
	Ash	6.97	7.25	7.57	....
		100.00	100.00	100.00	100.00
	Calories	6824	7100	7407	8014
	British Thermal Units	12283	12780	13333	14425

No. 12 Coal.

The vertical position of No. 12 coal is immediately above the limestone that overlies No. 11 coal. The interval between the two coals is irregular. In places No. 12 lies directly on the limestone which, in the Nortonville quadrangle, averages 4 feet in thickness. Further east a shale overlies the limestone and No. 12 coal is separated from No. 11 by an interval as great as 17 and even 21 feet. The coal is very irregular in thickness and in many places it is represented by a black smut or is entirely absent.

The only place in the Nortonville quadrangle where No. 12 coal has been worked at all is in the Nortonville mine. Here it was exposed in a small fault in the eastern part of the mine and a small amount of it was taken out and shipped with the other coal. It was about 4 feet in thickness and was regarded as an excellent quality of coal. Where No. 12 coal occurs of sufficient thickness to be mined as a commercial coal it has always been regarded as an excellent steam coal with a low sulphur and ash content. In localities where it is thin its quality becomes more variable. The soft shale roof which overlies the coal has, under present mining conditions, prohibited the mining of the coal.

Higher Coals.

In the region north of the Nortonville quadrangle two or three workable coals are reported in the 400 feet or more of Pennsylvania rocks which overlie No. 12 coal. They are all of a pockety nature and, except for certain well-defined areas, are of only local importance.

The most important of these higher coals is the one which lies about 130 feet above No. 11 coal and is known by several different names. It is the coal now worked at the No. 5 and No. 7 mines at Clay, where it is known as the Baker coal, a name first proposed by Doctor L. C. Glenn in Bulletin No. 17, Kentucky Geological Survey. In Bulletin No. 19 Mr. F. M. Hutchinson called it No. 14 coal.

Very little definite information has been published on these coals and the following sections were made by the writer while engaged in collecting samples of coal for analyses from the Western Kentucky coal field.

Section in Smith Mills Mine, Henderson County.

	Feet.	Inches.
Dark shales containing reeds, logs, ferns, etc.		
Aluminous gray shale	0	6
Coal, knife-edge thickness.		
Aluminous gray shale	0	1
Coal, knife-edge thickness.		
Clay shale	0	8
Coal ....6 feet 6 inches to	7	2
Laminated shale floor.		

Section Corydon Mine, Henderson County.

	Feet.	Inches.
Gray shale containing reeds, ferns, logs, etc.		
Coal, with clay parting near center	0	3
Fire clay	0	3½
Blue shale	0	6
Coal	5	0
Shale or laminated clay.		

In the Smith Mills mine there are two thin bands of coal with 1 inch of shale between, above the main body of the coal. In the Corydon mine these thin bands of coal thicken and form a rider of coal with a thin clay parting near the center.

Section in No. 7 Mine, at Clay, Webster County.

	Feet.	Inches.
Gray aluminous shale filled with impressions of ferns, reeds, logs, bark, etc.		
Coal, knife-edge thickness.		
Shale	0	1
Coal, knife-edge thickness.		
Bluish gray clay slickensided....1 foot to	2	7
Coal, maximum thickness	7	6¾
Shale, intercalated with coal	0	6 to 8
Gray fire clay.		

The two thin bands of coal above the main coal in places unite with a thin clay parting between.

Section of Nebo Coal, 2 Miles South of Nebo, Hopkins County.

	Feet.	Inches.
Shale	8	
Coal	0	9 to 11
Clay	0	3½
Coal, knife-edge thickness.		
Clay or gob	2	10
Coal, main ......6 feet to	6	6
Shale intercalated with coal bands	0	6-8

The two thin coals above the main coal are present here as at Clay, Corydon and Smith Mills, except that at Nebo the upper band was thickened to a maximum of 11 inches. The thin clay parting is also thicker at Nebo. The clay or gob immediately above the main coal has thickened to 2 feet 10 inches.

Section of Gish Mine, Kinchelo Bluff.

	Feet.	Inches.
Coarse sandstone.		
Shale, filled with leaf impressions, ferns, etc.	3	
Rash coal with large sigillaria trunks	0	2
Slate	0	½
Coal	0	2
Slate	0	½
Clay	0	1
Coal, upper bench	1	6
Clay parting	0	½
Coal, lower bench	3	7
Fire clay	0	6
Coal	0	8 to 12
Shale	15	
Sandstone.		

The coal from the Gish mine is described by F. M. Hutchinson in Bulletin No. 19, Kentucky Geological Survey as coal No. 14.

At Nortonville a coal was formerly worked by drift that was doubtless at the same horizon as the Baker and Nebo coals. The coal was of such poor quality that the mine was soon abandoned and a shaft sunk to the No. 11 coal. In describing this upper coal at Nortonville Doctor L. C. Glenn, in Bulletin No. 17, Kentucky Geological Survey, page 54, says: "This Nortonville coal had a very poor roof and the coal itself was rashy

and bony. The abandoned workings are now badly fallen in, but where accessible in the main entry, the coal is badly weathered and disintegrated and is very dirty. Where examined 5 feet of coal were visible and 9 inches or slightly more were under water. The top 12 inches is cleaner and better than the rest. The bone and rash are in very thin streaks scattered irregularly through the other 4 feet visible. Over it were 6 inches of soft clay shale, then 4 inches of coal, then 3 feet of rotten crumbling shale, dark with thin streaks or laminae of coal. Over this there is a massive soft sandstone 60 feet or more in thickness."

Doctor Glenn continues by giving the following log of a bore hole which was sunk 75 feet northwest of the powder house:

Bore Hole at Nortonville.

	Feet.	Inches.
Surface	17	
Coal (Nortonville or No. 14)	5	
Fire clay	2	
Soapstone	25	
Sandstone	34	6
Black slate	2	
Coal	1	6
Fire clay	6	6
Sandstone	21	6
Shale	2	6
Dark soapstone	10	
Gray slate	12	
Coal (No. 12)	6	
Fire clay	2	6
Limestone	5	
Coal (No. 11)	6	6
Fire clay	2	
Soapstone	30	
Shale	31	
Soapstone	10	
Black slate	3	
Coal (No. 9)	4	8

The uppermost coal shown in the above bore hole is 131 feet above the top of No. 11 and 213½ feet above the top of No. 9 coal. A massive sandstone 60 feet thick

outcrops in the hill just south of the Nortonville shaft. The base of this sandstone is close above the top of the uppermost coal shown in the above bore hole record.

MINING AND MINING METHODS.

Pick mining and shooting on the solid are still practiced in most of the smaller mines working the thinner coals. In these mines the coal is conveyed to the shaft or mouth of the mine in wooden cars drawn by mules.

The three large mines located at Nortonville, Mortons Gap and Graham are provided with modern equipment. The mines are furnished with mining machines for undercutting the coal. The puncher machines, driven by compressed air, are in more common use than the breast machines. Electric motors are used on all of the main haulage ways, and the mines are lighted by electricity.

The mines at Graham and Mortons Gap are working No. 9 seam and enter the coal by drift, while the Nortonville mine is working No. 11 coal by shaft at a depth of 203 feet below the surface. The coal from these mines is screened into a number of sizes from small pea to the largest lump. None of the plants is equipped with washers. Box car loaders are installed at some of the mines.

All of the mines in this region employ some modification of the room and pillar method. By this method from 35 to 40 per cent. of the coal is left in the ground. The operators say they find it does not pay to pull pillars and ribs, the present small demand for coal and the keen competition that exists compelling them to produce the coal at the lowest possible cost. The coal left in the mine is generally considered lost beyond recovery. A method proposed in England by Sir William Ramsey to utilize the coal in abandoned mines and also that in veins too thin to be worked otherwise, was to burn the coal in situ, bring the gases generated to the surface and utilize them. This method has not, however, been practically tested and its utility is not at all assured.

MARKET FOR WESTERN KENTUCKY COALS.

Some of the larger coal companies have coal yards and offices in Louisville, where a small percentage of Western Kentucky coal is shipped. Here it comes in competition with the Eastern Kentucky, West Virginia and Pennsylvania coals. At Evansville it comes in competition with the Indiana and Illinois coals. The most open market, therefore, for the Western Kentucky coals is that part of Kentucky lying south and west of the coal fields, Central and Western Tennessee, Mississippi and Louisiana. Paducah, Memphis, Nashville and New Orleans are the largest distributing centers. Some of the railroad companies with lines leading west out of New Orleans use a large amount of Western Kentucky coal.

The two railroad companies penetrating the Western Kentucky coal field are the Illinois Central and the Louisville & Nashville and their subsidiaries.

Green River, which is navigable throughout the year, enters the western coal field in Butler County, flows in a general northwest direction near the center of the basin, and joins the Ohio River 12 miles above Evansville. At the present time Green River carries a very small percentage of coal from this field, but with proper equipment of boats a large trade could be built up along this stream, as it crosses the successive outcrops of all of the coals of this region.

From Hawesville to Caseyville the Ohio River flows across the coal field approximately at right angle to the general course of Green River and offers exceptional advantages for the transportation of coal to southern markets and for shipment through the Panama Canal.

Mention has been made of the territory where the Western Kentucky coals must find their market and the competition in this market with the coals from Illinois, Indiana, Eastern Kentucky and Alabama. The keenest competition is with the Illinois and Indiana coals. The character and composition of some of the Western Kentucky, Illinois and Indiana coals are shown in the following tables of analyses.

The Western Kentucky coals are bituminous, and, compared to Eastern Kentucky, West Virginia and Penn-

sylvania coals are relatively high in volatile matter, ash and sulphur. They are free-burning, non-coking coals mainly used for domestic heating and steam generation. The high amount of volatile matter they contain renders many of them excellent coals for use in gas producers.

The two principal commercial coals of Western Kentucky, Nos. 9 and 11, contain a comparatively large amount of sulphur, although where properly treated this can be reduced. When these coals reach markets like Nashville, Memphis and New Orleans the cars loaded with lump coal contain a large amount of slack, thus giving a decided advantage, in appearance, to the harder coals from Eastern Tennessee and Eastern Kentucky. The Western Kentucky coals do not stand shipping as well as the harder eastern coals, although a part of the slack in nut and lump may be due to improper screening. At any rate, the Western Kentucky coals do not have the same clean appearance that the harder eastern coals have, and this fact alone has been hurtful to the Western Kentucky coals.

However, by comparing the B. t. u. of the Western Kentucky coals with those of the eastern coals at the prevailing prices of each coal in cities like Louisville, Nashville and Memphis, a saving of 10 to 50 per cent. may be realized by using the Western Kentucky coals.

In this connection it is of interest to note that recent experiments in Illinois* on bituminous coals, coke and anthracite show that "first class Illinois coals for domestic purposes can be purchased for one-half or less than one-half the price of anthracite. While the heating power of the anthracite is in general greater, the difference is not so great as to be in any sense commensurate with the difference in price. In one case the Illinois coal costs 46 per cent. of the price of the anthracite coal and contains 96.7 per cent. of its calorific capacity. In the other case, the Illinois coal costs only 34 per cent. of the anthracite and contains 82.5 per cent. of its calorific capacity."

*Year book for 1908, Illinois Geological Survey, pages 223-228.

The same applies to Western Kentucky coals, as shown by the following comparisons. The calorific value based on air-dried samples of No. 5 coal from Illinois, shows a general average of 12593 B. t. u. for 63 samples. Analyses of No. 9 coal from Kentucky on the same basis (No. 9 coal of Kentucky is the same as No. 5 coal of Illinois) show an average of 12366 B. t. u. for 82 samples. By eliminating five samples of exceptionally poor quality the average is 12421 B. t. u.

From the analyses of 115 samples of No. 6 coal of Illinois (the same as No. 11 coal of Western Kentucky), on an air-dried basis, the average B. t. u. is 12630. The analyses of only 38 samples of No. 11 coal from Western Kentucky show an average of 12582 B. t. u. The greater number of analyses of the Illinois coals gives a slightly higher average than is obtained from the analyses of the same coals from Western Kentucky.

While the quality of the Western Kentucky coals is inferior to the coals of Eastern Kentucky, West Virginia and Pennsylvania, the low price which the consumer pays for the Western Kentucky coals, from Louisville to the south and west, furnishes more calorific power per unit of coal at the prevailing prices for the low-priced coal than for the higher-priced eastern coals.

As an example, Western Kentucky lump coal retails in Louisville for $3.00 a ton and delivers 4,285 heat units for a dollar. Pocahontas smokeless coal in Louisville retails for $5.25 a ton and delivers only 2,908 heat units for a dollar, or a difference of 47 per cent. in favor of the Western Kentucky coals. This comparison, however, does not take into consideration the handling of a greater amount of the Western Kentucky coal and the production of a greater amount of ash in producing a definite number of calorific units. The balance, however, in favor of the Western Kentucky coals is so great that, after deducting the difference in cost of handling the high ash Western Kentucky coals, there will still be a large margin in favor of the latter.

The difference is still greater in the case of anthracite coal; and somewhat less than half this amount in the case of the Eastern Kentucky coals. To obtain the results given above it is necessary to have furnaces espe-

cially prepared for burning Western Kentucky coals, but the saving in using these coals will more than justify the expense of installing them.

The character and composition of Western Kentucky coals, based on the analyses of air-dried coal, are shown in the following table. The coals were collected in the mines by the Standard method adopted by the U. S. Bureau of Mines and the analyses made in the laboratory of the U. S. Bureau of Mines, at Pittsburgh, Pa.

		No. 9 coal. 82 samples.	No. 11 coal 38 samples.	No. 14 coal 20 samples.	Empire-Mannington coal. 11 samples
Moisture	a.	4.40	3.94	5.38	4.60
	b.	1.75	2.05	2.71	3.55
	c.	8.85	6.00	8.85	5.39
Volatile matter	a.	38.54	39.40	36.52	38.90
	b.	35.98	37.84	34.15	36.90
	c.	41.74	42.18	38.30	41.35
Fixed carbon	a.	46.60	47.13	48.65	51.82
	b.	42.25	46.57	43.45	49.94
	c.	51.19	50.44	53.46	56.40
Ash	a.	10.28	9.20	9.46	4.68
	b.	6.99	5.64	6.45	1.75
	c.	14.78	12.27	13.60	6.95
Sulphur	a.	3.59	3.95	2.39	3.49
	b.	2.27	3.21	1.13	.90
	c.	5.75	4.98	3.97	3.86
B. t. u.	a.	12291	12582	12248	13215
	b.	11446	11903	11362	12973
	c.	13865	13153	13424	13592

a.—Average for the number of samples given under each coal.
b.—Lowest.
c.—Highest.

From two to nine samples of coal were taken from each mine for analysis, and from these a general average was made. These general averages, representing as many mines, were then combined for the results shown in the above table.

THE COALS OF THE DRAKESBORO QUADRANGLE.

BY

A. F. CRIDER

1914.

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LOCATION.

The region covered by this report is known as the Drakesboro quadrangle and is bounded by meridians 87° and 87° 15′ and by parallels 37° and 37° 15′. It is situated on the southern border of the Western Kentucky coal field. The greater part of it lies in southern Muhlenberg, but it also includes a small portion of northern Todd and Logan Counties. Drakesboro, the town from which it derives its name, is located in the northeastern part. The total area of the quadrangle is approximately 238 square miles.

About five-sixths of the area comprised within the quadrangle is underlain by Pennsylvanian formations, or what is more commonly known as the "coal measures." This term "coal measures," however, is often misleading since it conveys the idea that coal may be found wherever such rocks occur. While this is to a certain extent true, there is a vast difference between "coal" and "workable coal." It may be the difference between a barren, rough, unproductive worthless region and one of vast latent or active wealth. The application of the above statement to the Drakesboro quadrangle is that five-sixths of the area is underlain by Pennsylvanian or coal measure rocks, whereas only one-sixth contains coals of sufficient thickness to be profitably worked on a commercial basis. Other coals are found in the remaining four-sixths of the quadrangle covered by Pennsylvanian rocks, but they are only thick enough and of sufficient extent to be occasionally available for local use.

In the Drakesboro quadrangle the only two coals that at present may be considered workable are Nos. 9 and 11. The areas underlain by these coals and the remainder of the Pennsylvanian, where coals of uncertain thickness and extent are present are shown by different colors on the map. The Mississippian rocks are represented by the uncolored area.

PREVIOUS REPORTS.

The first report in which mention is made of the coals of that part of Muhlenberg County included in the Drakesboro quadrangle was made by W. W. Mather in the "First Geological Report on Kentucky, 1838." In that report Mr. Mather describes two outcrops of coals at Vaught's Mill on Pond Creek. The lower coal he describes as being 4½ feet thick, overlain by shale. Another coal, 70 feet above the lower coal, he describes as being 6 feet thick. He says, "It contains some shale, and is covered by a bed of shale, and this latter is overlaid by a thin bed of limestone." The two coals thus described are evidently Nos. 9 and 11 coals of the present nomenclature.

At the time of Mr. Mather's visit to that region Mr. Buckner had just erected a large blast furnace on Pond Creek, 5 miles southeast of Greenville. He also mentions the presence of what is described in this report as the Sharber's Store fault.

Dr. David Dale Owen, in Volume I., Old Series, Kentucky Geological Survey, describes a few outcrops of what are now known as Nos. 9 and 11 coals in the hills north and northwest of Greenville. On pages 138 and 140 he mentions the occurrence of one or two of the lower coals and iron ores which were used at the old Buckner furnace.

In Volume IV. of the Owen Survey, Sidney S. Lyon, Topographical Assistant, in extending the base line through southern Muhlenberg County, mentions the presence of coals six miles southwest of Greenville and also the presence of the basal Pennsylvanian sandstone on Clifty Creek.

In the same volume a general section is given of Muhlenberg County by Leo Lesquereaux, and a discussion of the coals southwest and south of Greenville.

In Volume I. of the Shaler Survey Professor C. J. Norwood gives a section along what is now the Illinois Central Railroad which crosses the northwestern corner of the Drakesboro quadrangle, and discusses to some extent the coals in the region of Greenville.

TOPOGRAPHY.

The area included in this report was originally a plain sloping gradually to the north. Long continued stream action has so modified the surface that at present it is greatly dissected into hills and hollows. The divides between the larger streams are generally narrow, giving rise to a relatively small area of level upland. There are three areas of upland that have suffered less erosion than elsewhere. The largest of these is in southern Muhlenberg between Long and Caney Creeks between Bivins and Hardeson schools. In places this level land is a mile across. The second largest upland area is on the border lines of Muhlenberg and Todd Counties, in the region of Jason school. The third area is on the southern border of the quadrangle about in the center from east to west.

All of the streams in the southern half of the quadrangle are entrenched in narrow valleys with steep sandstone or limestone cliffs. Most of these valleys are so narrow that they afford very little tillable land. Farming operations are largely confined to the uplands.

Quite the reverse is true in the northern half of the area, where the larger streams have broad flat bottoms which in places attain a width of two miles. Even the small streams have relatively wide valleys which extend far up toward the sources of the streams.

This difference in width of the stream valleys of the southern and northern halves of the quadrangle is due to the nature of the rocks through which the streams flow. In the southern area the surface rock is largely a hard resistent sandstone which yields very stubbornly to the erosive action of the streams which occupy the valleys. In the northern area the predominating material is a soft shale which yields readily to the action of the streams.

The highest point in the quadrangle is on the extreme southern border, near the center from east to west, where the elevation is between 820 and 840 feet above sea level. The lowest point is on the northern border north of Elk Valley, where the elevation is a little less than 400 feet above sea level, giving a total relief

of about 440 feet. The highest point along the northern border is 660 feet, or 160 feet lower than the highest point on the southern border. Viewed as a whole, the region slopes gently to the north at the rate of about 9 feet to the mile. The relief in any locality varies from a maximum of about 300 feet in the south to 200 feet or less in the north.

DRAINAGE.

The entire area is drained by tributaries of Green River, which, at its nearest point, comes within 1½ miles of the northeastern boundary of the quadrangle. The western one-third drains into Pond River, which is itself a tributary of Green River, and barely enters the quadrangle at two places along the western border and crosses the southwestern corner. The three tributaries to Green River in the eastern part of the quadrangle are Pond Creek, which drains the central and northern areas and runs in a north-northeast direction; Rocky Creek, which drains the eastern and southeastern areas; and Clifty Creek, which drains a small area in the southeastern corner. The principal tributaries to Pond Creek are Caney Creek, Claylick Creek, Batiste Creek, Beech Creek, and Plum Creek. The two most important tributaries to Rocky Creek are Sulphur Spring Creek and Hazel Creek. The latter unites with Rocky Creek a short distance east of the eastern boundary of the Drakesboro quadrangle.

The larger streams entering Pond River from this area are Horse Creek, Cow Creek, Caney Creek, Long Creek, Jarrells Creek, and Spurlins Creek.

The dividing ridge between the waters of Green and Pond Rivers forms a meandering line which enters the quadrangle from the south a short distance southwest of Shelton school and extends northward to near Jenkins' store, where it turns northwest, passing Lead Hill school, to Weir. There it again turns northward to one mile west of Greenville, thence again bearing to the northwest, passing between Luzerne and Depoy, and leaving the quadrangle near the northwest corner. The streams flowing west from this dividing line into Long

Creek are short, usually less than a mile in length, and have a vertical drop, in this short distance, of 175 to 250 feet.

The larger streams of the quadrangle are perennial, although the flow practically ceases in late summer. There is not sufficient flow or fall in the lower divisions of the larger streams to develop any great amount of water power.

CULTURE.

The main line of the Illinois Central Railroad passes through the northwestern part of the quadrangle connecting the towns of Depoy, Luzerne, Greenville, Powderly and Hillside. The Owensboro branch of the Louisville & Nashville Railroad enters the quadrangle from the north near Bevier, runs in a south-southeasterly direction, and leaves the quadrangle on the eastern border at Rocky Creek. Bevier, Elk Valley, Drakesboro, Browder and Belton are small mining towns on this railroad. A short branch line has been built to the Diamond Block mine, one mile east of Drakesboro, and another to the Beech Creek mine, which is located 2 miles northwest of Belton. Greenville, the county seat of Muhlenberg county, is the largest town in the quadrangle.

Eight large coal mines, three of which are located on the Illinois Central Railroad and five on the Louisville & Nashville Railroad, are operated throughout the year and furnish employment to a large number of men. Three other mines, which are also located on the Louisville & Nashville road, were formerly worked, but are at present closed. Over the remainder of the area agriculture forms the principal pursuit of the people. A summer and health resort of considerable local reputation is located at Diamond Springs, on Rawhide Creek, near the southeastern corner of the quadrangle.

All of the roads of the quadrangle are common dirt roads and are subject to the extreme conditions of deep mud in rainy seasons and dust in dry seasons. The road drag is used on most of the public roads; where it is used in a systematic manner good results are obtained.

GENERAL GEOLOGY.

STRATIGRAPHY.

The bed rocks forming the surface of the Drakesboro quadrangle belong to the Mississippian and the Pennsylvanian.

The Mississippian rocks consist of sandstones, heavy bedded limestones and shales. They form the surface of about one-sixth of the quadrangle, principally in the southwestern area south of Long Creek, and narrow strips along Rocky, Clifty and Rawhide Creeks, in the southeastern area. They are represented on the map accompanying this report by the uncolored area. They form the base on which the Pennsylvanian sediments were deposited. In the northern part of the quadrangle the top of the Mississippian is between 800 and 900 feet below the surface.

Between the Mississippian and the base of the Pennsylvanian is a marked unconformity caused by a long period of erosion and followed by a later submersion before the deposition of the Pennsylvanian on the eroded surface. In places deep stream channels were cut into the Mississippian rocks and subsequently filled with the basal sandstone of the Pennsylvanian.

The Pennsylvanian rocks consist of sandstones, shales, thin limestones, clays and coals. They include that part of the Pennsylvanian between the base of the basal pebble-bearing sandstone and a point 100 feet above No. 11 coal. Three hundred and fifty feet of Pennsylvanian strata lying above No. 11 coal come to the surface in the Central City quadrangle, which borders the Drakesboro quadrangle on the north.

Generalized Section of the Pennsylvanian Rocks in the Drakesboro Quadrangle.

	Feet.	Inches.
Red to dark micaceous sandstone	20	
Coal (No. 13)	2	
Shale	20	
Sandstone	30	
Shale	30	
Coal (No. 12)	4	
Shale	4	

	Feet.	Inches.
Limestone	4	
Shale	2	
Coal (No. 11)	7	
Fire clay	2	
Shale	30	
Sandstone	25	
Shale	20	
Black slate	2	
Coal (No. 9)	5	
Fire clay	1	
Limestone	1	
Shale	15	
Sandstone	10	
Shale containing iron concretions	10	
Coal	2	
Clay	1	
Limestone, impure dark colored	2	
Shale containing iron concretions, "Kidney beds"	25	
Black slate, false horizon of No. 8 coal	2	
Shale	23	
Black slate	3	
Coal (No. 8)	1	6
Clay shale	6	
Sandstone	55	
Coal (No. 7)	thin	
Sandstone, thin bedded	30	
Shale	20	
Sandstone	20	
Shale	15	
Sandstone	50	
Shale	15	
Limestone containing marine fossils	0	6
Coal	3	
Fire clay	1	
Shale, calcareous in lower part	30	
Limestone, with shale partings	20	
Coal	3	
Shale and sandstone	40	
Coal (Mannington)	3	6
Shale	73	
Sandstone	30	
Elm Lick coal horizon.		
Fire clay	1	
Blue sandy shale	30	
Soft sandstone	10	
Gray, hard, siliceous shale	40	

	Feet.	Inches.
Coal, reported in drill record	4	
Sandstone	20	
Shale with thin coal near top	70	
White, medium grain sandstone containing small quartz pebbles	60	
Shale weathering chocolate	40	
Soft stratified sandstone interbedded with shale	50	
Coal	thin	
Basal Pennsylvanian sandstone containing quartz pebbles up to 1¼" in diameter	75	
Total	1117	6

The above section includes all of the rocks from the base of the Pennsylvanian to about 100 feet above No. 12 coal, a total thickness of 1,121 feet. At no one place in the quadrangle is the entire section exposed. The greatest thickness of rocks observed at any one place was on Sulphur Spring Creek, one mile above its mouth, where the lower 300 feet of the section was made. The remainder of the section was made up from different natural exposures and well records from various parts of the quadrangle.

The section here given is somewhat at variance with the one given by Doctor Owen in his general section of Muhlenberg County.* The interval between No. 9 coal and the base of the Pennsylvanian rocks in his section is only 642 feet. The same interval as measured by the writer is 904 feet. Doctor Owen, in referring to the strata in Muhlenberg County, says: "Except that the strata are somewhat reduced, and that two banks of shales and sandstones are replaced by limestone, the distribution is about the same as marked on the section of Union County."

The thinning of the measures, as noted by Doctor Owen, is doubtless more apparent than real and is due to a portion of the lower rocks being hidden by the Sharber's Store fault. The presence of this fault is not mentioned as having been discovered by Doctor Owen. In the region southwest of Greenville, where the lower part of his section of the county was made, the displacement of the fault is between 300 and 350 feet, with the downthrow on the north. This amount of displacement, if not taken into account, would fully account for his reduction of the lower measures. A study of the measures below No. 9 coal in the extreme southern part of Muhlenberg County where the strata are undisturbed by large faults shows no evidence of any thinning of the strata. Two or three of the thin coals which come in the lower 300 feet of Pennsylvanian measures have been opened in the region of Diamond Springs and in northern Todd and southern Muhlenberg Counties. These lower coals were thought, by Doctor Owen, not to be present in this region.†

*Ky Geol. Survey, Vol. 4, page 399.

The lowest member of the Pennsylvanian, as shown in the general section, is a heavy bedded sandstone, which generally carries a greater or less percentage of rounded quartz pebbles. In all of the old reports of the Survey it has been known as the "conglomerate," or "Millstone Grit." It consists of a coarse water-worn sand which is highly cross-bedded and contains irregular bands of rusty iron ore. The pebbles are largely pure white quartz and vary in size from large sand grains up to 2 inches in diameter.

In the region west of the Drakesboro quadrangle the thickness of the sandstone varies from 75 to 125 feet, with an average of 100 feet. In the Drakesboro quadrangle it is only 75 feet thick, but thickens to 100 feet less than 3 miles south, in northern Todd County.

Immediately above the basal sandstone is a soft stratified sandstone interbedded with shale, with a total thickness of 50 feet. Above the second sandstone comes a bed of shales which weather to a chocolate color, with a thickness of 40 feet.

From 90 to 100 feet above the top of the basal sandstone is a fine grain, white sandstone 60 feet thick, which is also pebble-bearing. At no place, however, were the pebbles found to be over ½ inch in diameter. They are of the same material as those in the basal sandstone, but they are not so plentiful.

†Ibid, p. 400.

The dual nature of the pebble-bearing sandstone is more pronounced to the east than in this region. In portions of Edmonson and Grayson Counties the upper pebble-bearing sandstone is known as the Bee Spring sandstone* and varies from a few feet to 60 feet or more in thickness.

A short distance south of the southern edge of the Drakesboro quadrangle is a coal which comes below the basal pebble-bearing sandstone. It is worked in two or three places and is reported to be 3 feet thick. It was not seen in the quadrangle.

Close above the top of the basal sandstone is a thin coal which has been opened in a number of places on the upper waters of Rawhide Creek, but it is usually less than 3 feet in thickness. The position of this coal corresponds to that of the Nolin coal of Edmonson and Grayson Counties.†

Between the top of the upper pebble-bearing sandstone and the Elm Lick coal‡ is an interval of about 175 feet, which is largely made up of shales. In a well drilled a short distance east of the Drakesboro quadrangle a 4-foot coal is reported to have been penetrated 80 feet below the Elm Lick coal.

The interval from the Elm Lick or Mud River coal up to the Mannington coal is approximately 100 feet. The two coals are well exposed in the same hill just west of Wards bridge, two miles northeast of Twin Tunnels.

The horizon of the Elm Lick coal marks the place of an unconformity which accounts for the absence of this coal over large areas.

Immediately above the coal is a heavy bedded sandstone which, in places, cuts out the coal entirely or renders it too thin to be worked.

The interval between the Mannington coal and No. 9 coal is about 400 feet. This interval contains two coals that have proved to be of workable thickness for local

*Ky. Geol. Survey, New Series, Vol. II, page 27.
†Ibid, page 110.
‡The Elm Lick coal is well developed in Ohio and Butler counties and is the equivalent of the Mud River coal of Muhlenberg County. It has never been opened in the Drakesboro quadrangle but it is now worked on Hazel Creek, 1 mile east of the eastern edge of the quadrangle.

trade on the headwaters of Ponk Creek; and two thinner coals which are of no economic value in this region. The two latter coals are generally known as Nos. 7 and 8. The former occurs under a coarse sandstone and the latter under a black slate similar to that above No. 9 coal. These coals have been opened in a few places southwest of Greenville on the headwaters of Claylick Creek.

In a region where these thinner coals were the only available source of fuel they would be more generally worked, but with their proximity to No. 9 coal, which can be bought at the mines for 4 and 5 cents a bushel for the best lump, it is highly probable that the less reliable and thinner coals will remain practically untouched until the more cheaply-mined coals are exhausted.

The interval between No. 9 and No. 11 coals in this region varies from 75 to 85 feet. It is made up of about 50 feet of shale and 25 feet of sandstone. Further north in the Central City quadrangle the sandstone interval is replaced by shale.

The interval between No. 11 and No. 12 coals will be described in detail on a later page.

The Anvil rock sandstone, which is the first sandstone above No. 12 coal, is fairly persistent in this region. It occurs over a large area east and west of Drakesboro and in the hills west of Bevier and north of Luzerne.

The highest formation outcropping in the Drakesboro quadrangle is a red to dark micaceous sandstone which comes above the first coal above No. 12. It occurs in the ridge west of Drakesboro and also forms the crest of the ridge northeast of Drakesboro and west of Bevier.

GEOLOGICAL STRUCTURE.

The Drakesboro quadrangle forms a part of the extensive trough or spoon-shaped basin in which the coals of this region have been formed. This basin extends to the northwest as far as Southeastern Iowa. It includes the coal fields of Illinois, Indiana and Western Kentucky, and is known as the Eastern Interior coal field. The center of this extensive basin is a little south of Central Illinois. The basin is widest at that point and

gradually narrows to the southeast and northwest. The Drakesboro quadrangle occupies a portion of the southernmost extension of this coal field.

There is a possibility that the southeastern end of this coal field was originally connected, through Southern Kentucky, with the Appalachian coal field. At present, however, the two coal fields are separated by a distance of 65 miles and all traces of Pennsylvanian rocks across this gap, if deposited, have been removed.

FAULTS.

From the Ohio River, along the southern border of the basin, to Green River, the original structure of the strata has been disturbed by oscillations, warping and faulting. In parts of the Drakesboro quadrangle this disturbance has been so marked that it is difficult to determine the relationship of some of the horizons coming below No. 9 coal. The disturbance consists of a series of faults whose general trend varies from a few degrees north of east and south of west to a few degrees south of east and north of west. The greatest complication arises where large blocks between two roughly parallel faults have been dropped with relation to the areas to the north and south. In other places there is a series of step faults where each successive block to the north has dropped lower than the one to the south. The nature of such faulting has been to give the impression of a very strong northward dip to the strata.

In regions where the fault lines intersect the crop lines of Nos. 9 and 11 coals these coals have been thrown out of their normal positions and considerable inconvenience and expense have attended the mining of these coals. The presence of Nos. 9 and 11 at a certain elevation has led those not familiar with the position and nature of the faults to expect the coals at the same elevation in nearby hills. Test holes or outcrops in sufficient numbers to fully determine the position of the coal to be worked should always precede the opening of a mine and determine its location. To pursue a different policy in some parts of this region may mean disaster.

The faults of this region belong to the type generally known as "normal faults," where one side has dropped by vertical shearing. The faults may be attended by a slight bending of the strata for a greater or less distance on one or both sides of the main shear, but in many of the faults the coals are undisturbed up to the fault plane. For this reason a fault may or may not be detected at the surface. Such faults, however, if located before a mine is opened, need not cause any great inconvenience in mining the coal. The known presence of faults in a coal region makes it all the more necessary that bore holes should be put down in advance of opening mines.

SHARBER'S STORE FAULT.

This fault was traced by numerous exposures from a point near Atkinson school house near Sharber's store, in the Nortonville quadrangle, to the western edge of the Drakesboro quadrangle. It enters the Drakesboro quadrangle 1½ miles north of Long Creek, where it has a bearing of north 84 degrees east. It is plainly discernible in the Weir road, one-half mile south of Sheldon school house, where its direction is north 80 degrees east. From here it veers slightly to the north and shows in the rocks at Claylick Creek, one-fourth of a mile north of Dixon's store, and is probably the same fault which shows so plainly in the Bowling Green road at Lees school house. From here eastward it apparently fades out before reaching Belton. The downthrow of the Sharber's Store fault is on the north. The amount of displacement at the western edge of the Drakesboro quadrangle is approximately 350 feet. At Lee's school house No. 9 coal, just north of the fault, is only 140 feet above the outcrop of a coal, 1½ miles to the southeast, that is here referred to as the Mannington coal. With a northward dip of 100 feet to the mile the amount of displacement in the fault at this point is approximately 185 feet. The rocks on the north side of the fault throughout this quadrangle dip rapidly to the north for some distance from the fault plane.

McCLELLAN SCHOOL FAULT.

In the road just south of McClellan school house the upturned edges of the strata indicate the presence of a fault at that place. A bed of limestone, which a short distance to the west has a thickness of 20 feet, has been caught in the fault. The rocks in the fault plane stand at an angle of about 90 degrees. The rocks from the fault plane northward to the school house, and for some distance beyond, dip strongly to the north. The general direction of this fault is south 80 degrees east, although individual measurements at different places on the fault vary from east and west to south 70 degrees east. The same fault appears in the road one-half mile west of McClellan school house and again in the hill just west of Saltlick Creek. It intersects the Sharber's Store fault just south of Sheldon school house, where the latter fault appears to change its original direction and veers slightly to the north. The McClellan School fault was not seen southeast of McClellan school house.

TWIN TUNNELS FAULT.

What appears to be a zone of considerable disturbance occurs in the latitude of Twin Tunnels. The disturbance is in the nature of a primary or main fault, with smaller adjustment faults to the north and south. The effects of the fault are very pronounced in the railroad cut at Twin Tunnels, in the Greenville and Russellville road two miles west of Twin Tunnels, and to a less extent in the road south of Wells. The general direction of the main fault is south 80 to 85 degrees east. It intersects the Sharber's Store fault just north of Dixon's store and is not discernible west of that point. It continues eastward into the Dunmor quadrangle as far as Mud River mine, where it apparently fades away.

The character of the disturbance is best shown at Twin Tunnels, where the railroad cuts through the narrow divide at right angles to the main fault plane. The main fault shows a vertical shear with the downthrow on the north. At a point 1/4 mile to the north is a secondary fault with the downthrow on the south. The direction of the secondary fault is north 75 degrees east.

A short distance south of the main fault is a secondary fault with the downthrow on the north. About 100 feet south of this secondary fault is a small sharp anticline in the sandstone which stands at an angle of 15 degrees on the north limb with a slightly smaller dip on the south limb.

The rocks along the Bowling Green and Greenville road have a strong northward dip for a distance of one mile north of the main fault.

BROWDER FAULTS.

In sinking the shaft at the Browder mine No. 11 coal was struck at a depth of 185 feet. At a point 1,200 feet north 32 degrees east of the shaft a fault was encountered in the main entry with a trend of north 77 degrees east. No. 9 coal north of the fault was found 29 feet higher than No. 11 south of the fault. The two coals are here normally 76 feet apart, which would give 105 feet displacement in the fault. This is known as the North Browder fault.

On investigation what appears to be the main fault appears about half way between Browder and the Browder mine with a general direction of north 75 degrees east. No. 9 coal south of the main fault occurs at an elevation of 500 feet or 356 feet above the same coal in the block in which the Browder shaft is located. This fault, with the exception of the Sharber's Store fault, has the greatest displacement of any fault in the quadrangle.

ROCKY FORD FAULT.

A fault having a bearing of north 81 degrees east crosses Pond River at Rocky Ford. It apparently fades out to the west before reaching Greenville. It continues east of Rocky Ford to the Peanut fault, where its eastward extension is cut off.

The amount of displacement in the fault at a point one mile west of Rocky Ford is 120 feet, as shown by the outcrops of Nos. 9 and 11 coals. Just north of the fault No. 9 coal occurs on the crest of the hill at an elevation of 500 feet. South of the fault No. 11 coal is opened at the Browning mine at an elevation of 460 feet.

Assuming these coals to be normally 80 feet apart the amount of displacement in the fault is 120 feet, with the downthrow on the south. North of the fault a strong eastward dip carries No. 9 coal down to an elevation of 420 feet just north of Rocky Ford, and from there eastward to the Peanut fault the rocks are practically level. South of Rocky Ford fault and west of Pond River the dip is likewise strongly to the east.

The area lying north of the Sharber's Store fault, east of Pond River and south of Rocky Ford fault, and including four small outliers of No. 9 coal west of Pond River, is largely underlain by No. 9 and in places by No. 11 coals. The presence of these coals in this region is the result of faulting, aided in places by a southward dip. The normal position of No. 9 coal, without the influence of faulting, is clearly shown in the outcrop of this coal from Powderly to Elk Valley. As a result of the peculiar faulting which has attended this region the southern outcrop of the coal has been extended three to four miles further south than it would have been without the influence of faulting.

It is interesting to note that immediately south of the southern projection of the No. 9 coal area there is a corresponding southern projection in the outcrop line of the basal Pennsylvanian members. It is quite probable that the same cause which produced the southward extension of the No. 9 coal area operated to produce the same results on the basal members of the Pennsylvanian rocks.

PEANUT FAULT.

In driving the west entry in the Peanut mine a fault having a displacement of 32 feet was encountered a few feet west of the shaft. The downthrow is on the southwest side. The actual direction of this fault was not determined as the mine was closed at the time of the writer's visit.

In the main west entry of the Black Diamond mine at Drakesboro there is a strong southwest dip, which, for a short distance west of the shaft, is 5 degrees. The direction of the entry is south 72 degrees west and at right angles to the strike. The Peanut fault apparently loses its characteristics as a fault before reaching Drakesboro and merges into a sharp monocline.

The level of No. 9 coal at the bottom of the shaft in the Black Diamond mine is about 30 feet lower than the level of the same coal at the Diamond Block shaft ½ mile east of Drakesboro. It is probable, however, that the greater part of this difference is due to dip, which is to the south and west.

MINOR FAULTS.

The above described faults are the ones which by reason of their displacement, have to a marked degree affected the stratigraphy of the region. There are, in addition, perhaps a larger number of smaller faults which it is impossible to trace for any great distance. Many of these are subsidiary to the main faults already described, and some entirely independent of them.

In the region of Friendship school house, 3 miles southwest of Greenville, the broken and upturned edges of the strata indicate the presence of a northwest-southeast fault. So far no faults of any consequence in this quadrangle have been encountered in working No. 9 coal north of Rocky Ford fault.

DIPS.

South of the Sharber's Store and Twin Tunnels faults the prevailing dip is to the north. In the southwestern quarter of the quadrangle the rate of dip is approximately 40 feet to the mile. In the southeastern quarter it is less than 30 feet to the mile. Along the southern border of the quadrangle there is an eastward dip from the headwaters of Cow Creek to Johnson Bridge of 44 feet to the mile. This dip does not continue to the eastern edge of the quadrangle. In fact, from the eastern border of the quadrangle to Johnson Bridge there is a slight reverse dip which amounts to 20 feet in that distance.

Between Sharber's Store fault and the outcrop of No. 9 coal, in the northwestern quarter of the quadrangle, the dip is to the north. In places the rate of dip is

increased by faults. The northward dip, as shown by the elevations of No. 9 coal, is from 35 to 45 feet to the mile. From Depoy eastward to near Elk Valley there is an eastward dip in No. 9 coal of 10 feet to the mile. From Depoy westward to Pond River, on the north side of the Graham faults, there is a westward dip of 40 feet to the mile. Disregarding the effects of the Graham faults, which apparently fade out a short distance northeast of the northwestern corner of the Drakesboro quadrangle, there is a broad anticlinal axis extending north and south near the northwestern corner of the quadrangle.

The dips in the northeastern quarter of the quadrangle are greatly affected by faults. East of Pond Creek and north of the Browder faults there is a prevailing dip to the southwest. At Bevier No. 9 coal is at an elevation of 420 feet above sea level. At the Elk Valley mine the same coal has dipped to an elevation of 372 feet. At the Peanut mine the elevation of the coal is 341 feet, while at Diamond Block mine it is only 304 feet above sea level. The southward dip continues to the North Browder fault, where the elevation of No. 9 coal is 299 feet. Between the Browder fault and the Sharber's Store fault there is a steady northwest dip. In the Beech Creek mine the dip is at the rate of about 100 feet to the mile.

COALS BELOW NO. 9.

A number of thin coals, some of which are worked for local use, occur in the Drakesboro quadrangle south of the area containing No. 9 coal. The lack of transportation and the nearness to mines operating No. 9 coal have almost completely checked operations on these lower coals.

Mines on the lower coals are confined to two small localities: One on the headwaters of Pond and Saltlick Creeks, and the other on the headwaters of Hazel Creek in the region of Belton.

In the first mentioned locality what appears to be three different coals have been opened. The vertical interval between the lowest and highest is about 50 feet.

Both of these coals have been opened on P. H. Drake's land, the upper coal just north of and the lower coal 1/4 mile south of the Hopkinsville road and one mile northwest of Sheldon school house. The following section was obtained at P. H. Drake's:

Section at P. H. Drake's.

	Feet.	Inches.
1. Sandstone	40	
2. Coal	2	6
3. Shale, lower part containing calcareous concretions	30	
4. Gray, fossiliferous limestone in two benches with shale between	20	
5. Coal, reported to be	3	6

What appears to be the same limestone as shown in 4 of the Drake section was observed in three different localities along the McClellan School fault. Just west of Saltlick Creek along the line of the fault the limestone is 15 feet thick, but no coal was seen beneath it. The same limestone appears in the road just south of McClellan school house, and again 1/2 mile to the west. At the latter place it stands at a high angle due to a fault and is 20 feet thick. No coal was observed at either of these places.

This thickness of limestone in the Pennsylvanian of Western Kentucky is rather unusual. It has been observed in two or three places in the Nortonville quadrangle and in as many places in the Drakesboro quadrangle. East and west of these two quadrangles it either separates into two divisions or is entirely cut out. At three localities a coal is present close under the limestone and in other places the coal is absent. It is probable, therefore, that the surface in this region has been subjected to erosion and submerged just previous to the deposition of the limestone. This would account for the appearance and disappearance of the limestone, it having been deposited only in the depressions on the old eroded surface.

The higher coal shown in the Drake section is worked at the J. R. Jackson coal bank, one mile due

north of Sheldon school house. The elevation of the coal is about 460 feet. The coal has a sandstone roof, which is 40 feet thick at that place. The following is a section at the Jackson opening:

Section at Jackson Coal Bank.

		Feet.	Inches.
Soft sandstone, weathering yellow		40	
Coal	Top coal 8″; Middle bench 22″; Mother coal 3″; Bottom coal 6″	3	3
Fire clay, reported to be		7	

The same coal has been worked in time, but now abandoned, on the old Buckner furnace property, one mile east of the Jackson opening. The elevation of the coal is there 478 feet.

Section on the Buckner Furnace Property.

	Feet.	Inches.
Sandstone capping hill to the north.		
Shale	15	
Coarse, soft sandstone	40	
Coal	2	6
Fire clay floor	1	

Less than one-fourth of a mile due east of the Buckner furnace opening the same coal has been opened under a sandstone at 20 feet higher elevation, giving a strong dip to the west.

At a point one-half mile northwest of McClellan school house, in the deep hollow which heads just west of the school house, is an old opening on a coal that is reported to be 34 inches thick. The coal was not seen at any other locality in the Drakesboro quadrangle, but from the nature of the roof of the coal it is the one that is referred to in Dr. David Dale Owens' reports as coal No. 5. It occurs under a shale bed with a thick coarse sandstone above. In the Little Muddy quadrangle, in the region north of Morgantown, this sandstone attains a thickness of 100 feet. The following is a section at the mouth of the opening:

Section ½ Mile N. W. of McClellan School.

	Feet.	Inches.
Sandstone.		
Impure limestone which weathers to a brown rotten shale, and contains an abundance of marine fossils, sharks' teeth, fish scales, etc.	3	
Coal	2	10
Fire clay, reported.		

A coal having the same rotten limestone top with similar fossils is worked at a number of places north of Morgantown and is the same coal worked for so long at Mining City, on Green River, 6½ miles east of Rochester. The Hatcher coal, which is correlated with the Mannington coal in the Morgantown section, is approximately 100 feet below the above described coal.

The bottom of the thick limestone referred to above is something like 50 feet below the coal given in the last section. This would seem to correlate it with the Jackson coal and the coal under the 40-foot sandstone on the old Buckner furnace property. At the Jackson and Buckner furnace openings, however, the sandstone above the coal has cut out the fossiliferous limestone which forms the roof at McClellan school house.

From the best evidence obtained from a study of the coals in this quadrangle the coal, which occurs under the 20 feet of limestone at the Drake opening, is about 50 feet below the Jackson coal and an equal distance above the Mannington coal. This conclusion is strengthened by the relationship of the Cates coal to the Mannington coal in the Nortonville quadrangle, and the relationship of the Mining City coal to the Hatcher coal (Mannington coal) in the Little Muddy quadrangle.

The only place where the Mannington coal was identified in the western half of the Drakesboro quadrangle is in a well ¼ mile south of the Hopkinsville road, two miles due west of Sheldon school house. The coal is reported to be 5 feet thick. A thin limestone outcrops on the hill at a horizon 35 feet above the coal.

Along the Rochester road, between Belton and the Bowling Green road, a coal has been worked in a number of places. It occurs close under a coarse yellow-weathering sandstone and is perhaps the same coal that is

worked at the Jackson bank and on the old Buckner furnace place, north of Pond Creek. It is worked exclusively for local trade and is regarded as an excellent free-burning domestic coal.

Hazel Creek Mine.

A new mine was opened in the summer of 1914 at a point one-fourth of a mile southeast of Belton. The mine is opened by shaft on a coal that is correlated with the Mannington coal. The top of the shaft is at an elevation of 460 feet above sea level. The shaft is 68 feet to the coal, which is 4 feet thick without parting. At a point 38 feet above the coal is a hard blue limestone 5 feet thick. The limestone is in two benches with two feet of shale between. The entire depth of the shaft was dug through hard shale with an occasional thin sandstone and the limestone mentioned above.

What may prove to be the same coal as that being developed at Belton is shown in the following section just north of the Twin Tunnels fault:

Section in R. R. Cut at Twin Tunnels.

	Feet.
Shale	10
Coal	2 to 3
Hard, rough sandstone	10
Soft blue shale	10
Gray shaly sandstone containing irregular lenses of harder sandstone	30

No. 9 Coal.—The area underlain by No. 9 and No. 11 coals in the Drakesboro quadrangle are shown by separate conventions on the map accompanying this report. No. 9 coal is 75 to 80 feet below No. 11 coal, so that the area shown as underlain by No. 11 likewise contains No. 9 coal.

Geibel Mine.

The most western outcrop where No. 9 coal is worked in the Drakesboro quadrangle is in a small outlier just north of Depoy. The coal has been worked at this place, for local trade, for a number of years. It is worked by drift, the mouth of which is at an elevation of 575 feet.

Coleman and Wakefield Mine.

No. 9 coal is worked by drift on the east side of the deep ravine from the Geibel mine at an elevation of 570 feet. The mine is operated exclusively for local trade. The average thickness of the coal is 54 inches, with a variation from 52 to 56 inches.

Luzerne Mine.

The Luzerne mine is located on the hill north of Luzerne. It is operated by the W. G. Duncan Coal Company of Greenville. The first opening was made by drift on No. 9 coal on the south side of the hill ½ mile north of Luzerne. The elevation of the coal is about 525 feet. The coal has been worked out of the south edge of the ridge and a new opening made on the east side of the ridge at a point 1¼ miles west of north of the first opening. The elevation of the coal at the new opening is about 520 feet. The average thickness of the coal is 4 feet 8 inches without parting. The coal has a black slate roof 8 to 12 inches thick with a hard blue shale above. A hard fire clay forms the floor.

The plant is equipped with motor haulage on the main entries. A motor road has been built from the mouth of the new opening to the tipple at the old opening. Two 10-ton Jeffrey motors are coupled together for the outside haul, pulling 75 cars of coal at a trip. The motor road is constructed with standard size railroad ties with 45 pound rails on the outside and 40 pound rails on the main haulage ways inside, with 16 pound rails on the entries for mule haulage, and 12 pound rails in the rooms.

The rooms are 24 feet wide with two rows of posts 4 feet apart on each side of the center.

The northward dip of the coal in the new mine is 2 per cent. or less for the first 500 feet with a slight reverse dip for a short distance; then for a distance of 800 to 1,000 feet the dip to the north is 4 per cent. The east entries dip northeast to the crop and the west entries dip northwest to the crop.

HILLSIDE MINE.

At the old Oakland mine at Hillside No. 9 coal is reported to be 74 feet below the surface. The elevation of the surface at the shaft is 485 feet. The coal at this place has been worked out and a new opening made by drift on No. 9 coal at a point 1¼ miles northwest of Hillside, where the coal is at an elevation of 460 feet. Motor haulage is used to convey the coal from the new mine to the tipple at Hillside.

POWDERLY MINE.

No. 9 coal is worked at Powderly by the Greenville Coal Company. The coal is worked by slope. The average thickness of the coal is 5 feet. The mine is equipped with motor haulage, electric chain-breast machines and electric lights. The overburden is comparatively thin, which causes a poor roof under the valleys and swags.

Between Powderly and the Luzerne mine are a numger of small openings on No. 9 coal by which the crop line of the coal between these places was easily determined.

At a point ½ mile east of Powderly No. 9 coal is worked by slope for local trade. The elevation of the coal is 450 feet. The average thickness of the coal is 5 feet.

B. F. DRAKE OPENING.

No. 9 coal has been opened on B. F. Drake's land on the east side of the ridge, 2¼ miles a little south of east of Powderly. The coal at the mouth of the opening measured 5 feet 2 inches without parting. The elevation of the coal is 460 feet.

Just south of the Greenville road, ¾ mile south of the Drake opening, No. 9 coal outcrops near the crest of the hill at an elevation of 500 feet. A section exposing the strata below No. 9 coal is shown in the hill to the south.

Section ¾ Mile South of Drake Opening.

	Feet.
Surface.	
Coal, No. 9.	
Shale	15
Sandstone	10
Shale filled with iron concretions	10
Yellow limestone	1
Shale	50
Black slate—false horizon of No. 8 coal.	

No. 9 coal has been opened between Liberty school house and Elk Valley on the north side of Pond Creek. One of the openings is a short distance east of the school house, and the other in the deep ravine about half way between the two places.

The same coal has been opened at two places on the south side of Pond Creek between Rocky Ford and Peanut. The upper opening is near Rocky Ford and is known as the Picket opening. The coal is at an elevation of about 420 feet. The lower opening, one mile west of Peanut, is at an elevation of about 400 feet.

BEVIER MINES.

Two large mines are operating on No. 9 coal at Bevier. The one on the northeast side of the railroad is owned by the Crescent Coal Company, and the one on the southwest side is owned and operated by the Lam Coal Company. At the former the coal is opened by shaft 40 feet deep and at the latter by drift. The elevation of the coal is approximately 410 feet. In the Lam Coal Company's mine, where a number of samples of coal were collected for analyses, the coal varies in thickness from 4 feet 10 inches to 5 feet 8½ inches, with an average of 5 feet. The roof above the coal is a hard black slate, which stands in the rooms with very little timbering. The floor is a hard smooth fire clay. The following is a representative section at the face of the coal:

Section in Lam Coal Company's Mine.

	Feet.	Inches.
Coal, very hard	1	3
Sulphur band, not regular		1
Coal, hard		2½
Mother coal		¼
Hard coal	2	11½
Sulphur band—not regular		¾
Hard coal		6
Total	5	1

The two mines are equipped with chain-breast machines, motor haulage, automatic dump and shaker screens. Electric lights are used on the main haulage ways.

At the Crescent mine storage bins have been erected to supply railroad locomotives with coal. This is the most southern station on the Louisville & Nashville where locomotives are coaled at the mine.

ELK VALLEY MINE.

The Elk Valley mine is located a short distance north of Pond Creek, on the Owensboro and Nashville division of the Louisville & Nashville Railroad. The mine was flooded by the high water of 1913 and operation has been suspended since that time. The coal worked at this place was No. 9, which was worked by shaft which is 48 feet deep. The coal is reported to be 5 feet 6 inches thick without parting. The dip of the coal is 2 per cent. to the south.

PEANUT MINE.

The Peanut mine is located one-half mile north of Drakesboro. The mine was closed at the time of the writer's visit to that place. No. 9 coal was worked by shaft at a depth of 79 feet. The coal is reported to be 6 feet in thickness. A description of the fault in this mine is found on a preceding page.

BLACK DIAMOND MINE.

The Black Diamond Mining Company of Drakesboro is working No. 9 coal in the town of Drakesboro. The coal is worked by shaft, which is 132 feet deep. The coal averages 5 feet in thickness and in places it reaches a thickness of 6 feet 8 inches. It has a firm black slate roof and fire clay floor. The mine is furnished with modern equipment, consisting of chain-breast machines, motor haulage, self-dumping cages and shaker screens. No. 11 coal was originally worked in the Black Diamond mine, but was later abandoned for the No. 9 coal. The former occurs at a depth of 46 feet below the surface and 86 feet above No. 9.

DIAMOND BLOCK MINE.

The Diamond Block Coal Company is operating No. 9 coal by shaft ½ mile east of Drakesboro. A spur of the Louisville & Nashville Railroad built from Drakesboro to the mine furnishes an outlet for the coal. The coal was reached at a depth of 96 feet. The average thickness of the coal is 5½ feet. The coal has a good black slate roof and hard fire clay floor. The coal dips 1½ to 2 per cent. to the southwest. The mine produces more or less gas and unless a good current of pure air is constantly circulated through the workings it may cause a disaster similar to that which occurred at Browder.

BROWDER MINE.

The Browder mine is located on the east side of the railroad track at a point half way between Drakesboro and Browder. A shaft was sunk to No. 11 coal, which was found at a depth of 185 feet below the surface. The main entry is north 32 degrees east. At a point 1,200 feet from the bottom of the shaft a fault was encountered which cut off the coal to the north. The direction of the fault in the mine is north 77 degrees east. On investigation No. 9 coal north of the fault was found 29 feet higher than No. 11 coal south of the fault, showing a downthrow of No. 11 coal of 105 feet. The general conditions here are very similar to those at Nortonville.

After striking the fault an incline was made up to No. 9 coal and the two coals were worked from the same shaft.

In the summer of 1912 an explosion occurred in the mine in which 27 people lost their lives. In 1911 the mine was inspected six times by the Assistant State Mine Inspector and from 1½ to 3 per cent. of gas was found in the No. 11 workings at each inspection.

The mine had hardly recovered from the effects of the explosion when the tipple and boiler room burned. At the time of the writer's visit to the mine, in 1914, a new tipple made of long leaf heart pine had just been constructed and it was the intention of the company to resume operations at an early date.

BEECH CREEK MINE.

Beech Creek mine is located on a creek by that name 2 miles southwest of Browder, and about the same distance northwest of Belton. A spur which taps the Louisville & Nashville railroad ¾ mile north of Belton gives an outlet for the coal. The mine is owned and operated by the Beech Creek Coal Company.

No. 9 coal is worked from two openings. As will be seen from the map the coal is cut in two by Beech Creek. On the south side of the creek the coal is worked by drift, and the loaded coal cars are drawn from the mouth of the mine up to the tipple on the north side of the creek by means of a wire cable. The elevation of the coal at the mouth of the drift is 440 feet.

The main opening is on the north side of the creek where No. 9 coal is worked by shaft which is 29 feet deep. The main entry is down the dip, which is north 22 degrees west. At a point in the main entry 1,400 feet from the shaft the coal is 27 feet lower than it is at the shaft. The coal is nowhere less than 5 feet in thickness, with a maximum of 6 feet 6 inches without parting. The average thickness is 5 feet 6 inches. Slight folds or undulations are common. In some of the troughs of the folds are large "nigger heads" which protrude from the roof. The roof is a hard black slate which requires very little timbering at any place. The coal contains a very small amount of sulphur. The lack of sulphur and the excellent condition of roof and floor give the coal a clean, attractive appearance not often found in No. 9 coal of Western Kentucky.

HENDRIE MINE.

The Hendrie Coal Company, during the summer of 1914, was operating a new mine on No. 9 coal on the north side of the railroad, at a point one-half mile east of the Beech Creek mine. The coal will be worked by drift, and loaded into railroad cars from a tipple the top of which is but slightly above the level of the coal seam.

GRAY COAL BANK.

No. 9 coal has been opened on the southeastern point of the ridge 2 miles due west of Belton. The elevation of the coal is 522 feet. The mine is operated in the fall and winter months for local trade.

DWYER COAL BANK.

Pallace Dwyer operates a mine on No. 9 coal for local trade. The mine is located one-half mile northwest of Lee school house. The elevation of the coal is about 500 feet. The following section was made at the mouth of the mine:

Section at Pallace Dwyer Coal Bank.

	Feet.	Inches.
Black slate	2	
Coal, without parting	5	6
Fire clay	0	5
Limestone	1	
Clay	3	

ROUSSEAU SMITH COAL BANK.

No. 9 coal has been opened on Rousseau Smith's land just east of Pond Creek and one mile north of the Bowling Green road. The coal measured 5 feet thick at the mouth of the opening. The elevation of the coal is 450 feet, barometric reading, which is possibly 20 feet too high.

GREENVILLE FUEL COMPANY'S MINE.

The Greenville Fuel Company is operating on No. 9 coal at a point about one mile north of where the Bowling Green road crosses Pond Creek. The company has a large storage bin which is filled in late summer for fall and winter use. A large part of the coal mined at this place is hauled to Greenville for local consumption.

The elevation of the coal at the mouth of the mine is 480 feet. The coal averages 5 feet thick without parting. The lower 8 inches of the black slate, which forms the roof of the coal, is in the nature of a draw slate and unless it is well propped falls soon after the coal is removed. The coal dips a little north of east at about 1½ per cent.

BUCK KNOB OPENINGS.

Two openings have been made on No. 9 coal near the south end of Buck Knob. The one farthest west is at an elevation of 535 feet. It is known as the Tom Bell opening, but it is now abandoned. At the John Wells opening near the southeastern end of the ridge the coal is at an elevation of 520 feet. The coal is 5 feet thick under 2 feet of black slate.

DOCKINS COAL BANK.

At a point one-fourth of a mile west of Pond Creek and half that distance south of Rochester road is an opening on No. 9 coal known as the Dockins coal bank. The coal is worked by slope, and the coal drawn up the incline by wire cable operated by steam power. The elevation of the coal is about 395 feet. The coal is 5 feet 2 inches thick with 2 inches of rash which sticks to the roof. The dip in the mine is to the southeast.

The coal at the Dockins bank is 140 feet lower than the same coal at the Tom Bell opening on the west side of Buck Knob.

J. G. HALE COAL BANK.

On the north side of the Rochester road, 2 miles east of Greenville, J. G. Hale has a mine on No. 9 coal which is worked for local trade. The elevation of the coal is 480 feet. The coal is 5 feet 6 inches in thickness under a black slate roof. The upper 2 inches of coal is a rashy coal high in ash. For a distance of 20 feet above the coal is a shale with sandstone above. The dip in the mine is to the northeast. The dip is so strong that before reaching the eastern end of the ridge No. 9 coal has dipped to an elevation of 420 feet and No. 11 coal occurs up in the hill at an elevation of 505 feet.

On the east side of Pond Creek No. 9 coal is at an elevation of about 450 feet or 50 feet below the bed of the creek. From a bore hole, which was located in Pond Creek bottom, one-half mile north of the Rochester road it appears that No. 9 coal has all been cut out between Pond Creek and the eastern edge of the hill in which the Hale mine is located. The test hole was put down by the Pond Creek Coal Company and is known as Test Hole No. 1.

Log of Test Hole No. 1.

	Feet.	Inches.
Clay	30	
Blue quick sand	8	
Gravel bed	8	
Blue sandstone	8	6
Soapstone	8	6
Gray slate	17	6
Coal		6
Kidney bed	1	6
Black slate	3	6
Fire clay	2	
Soapstone	11	
Gray slate	33	
Black slate	2	6
Coal	1	6
Fire clay	2	6
Soapstone	6	6
Total	150	

COALS ABOVE No. 9.

No. 11 Coal.

No. 11 coal in the Drakesboro quadrangle, wherever normally developed, is from 75 to 85 feet stratigraphically higher than No. 9 coal. In seeking for this coal in the region where No. 9 coal is opened it may be found in the hills above the No. 9 outcrop, where the hill rises to a sufficient height above No. 9, or a short distance to the north. In a region where the two coals are present the natural outcrops of No. 11 are generally more numerous than those of No. 9. The reason for this is evident. The strata for some distance above No. 9 coal are shales which weather rapidly, and it is only in favored places where this coal is naturally exposed. Immediately above No. 11 coal is a very resistant limestone which is an easily recognized marker for the coal. The thickness of the limestone is from 3 to 5 feet, with an average of 4 feet. It is the only limestone of importance above No. 9 coal in this quadrangle, so that the presence of a thick limestone in the region surrounded by No. 9 coal may be assumed to be just above the horizon of No. 11 coal even if the coal itself is not exposed. The outline of the No. 11 area in the extreme northeastern part of the quadrangle was principally made on the evidence of the limestone, the coal in most instances not being exposed.

The outline of the No. 11 coal area is similar to that of the No. 9 area, except that the former is very much smaller than the latter. In the greater part of the quadrangle No. 11 coal occurs so near the crests of the ridges that the coal is full of dirt slips, due to breaks in the roof. The only places where attempts to work the coal on a commercial basis have been made are at Sunrise, Browder and Beech Creek. The Sunrise mine was abandoned on account of bad roof conditions. At Beech Creek No. 11 was abandoned for the more reliable and cleaner No. 9 coal. No. 11 was operated at Browder until the mine-tipple and boiler room were burned.

The most desirable territory for the operation of No. 11 coal in this quadrangle is between Drakesboro and Pond Creek, extending as far south as Beech Creek, and to a less degree in the region east of Drakesboro, north of the Browder fault. In places the coal is of exceptional thickness.

The characteristic features by which No. 11 coal may be distinguished from any other coal in this quadrangle are as follows:

First. It invariably has a limestone roof. In places the limestone may be separated from the coal by 4 inches to 2 feet of black slate, which resembles the black slate above No. 9. In other places a soft gray shale or "gob" takes the place of the black slate.

Second. A band of clay, known as the "blue band," is always present in No. 11 coal. It occurs about 2 feet from the bottom. Throughout Western Kentucky, and parts, if not all, of the Illinois and Indiana fields, the "blue band" is a characteristic feature of this coal. In the recent Illinois reports this coal is known as No. 6 coal, while in the Indiana reports it is known as No. 7 coal.

Third. An upper bench of very pure coal, generally known as "shop" or "gas" coal, is always present. A thin parting of sulphur or clay separates the shop coal from the main body of the coal. The shop coal is about 18 inches thick. The upper clay or sulphur parting and the blue band separate the coal into an upper, middle and lower bench. The purest coal comes at the top. The middle bench is a good hard coal that is regarded as a superior steam coal to No. 9 coal. The bottom bench usually runs high in sulphur.

The greatest drawback to No. 11 coal is the high ash content. This, however, is not all inherent in the coal, but is due in part to foreign matter which is mixed with the coal in mining. In mining, the "gob" or slate, which comes between the top of the coal and the overlying limestone, usually falls, and it is impossible to keep particles of clay from becoming mixed with the coal. The blue band is also a source of impurity which increases the ash content in the coal.

A large number of samples of Nos. 9 and 11 coals from Western Kentucky were collected in 1914 and the coals analyzed in the laboratory of the U. S. Bureau of Mines. The results of the analyses show No. 11 coal

to be slightly superior to No. 9 in heating value. The samples were all collected under similar conditions. However, in actual mining the ideal conditions that existed in collecting the samples will be more nearly realized in mining No. 9 than in No. 11 because of the greater amount of foreign matter that is liable to get into the latter. Where extreme caution is taken to exclude the foreign matter No. 11 is an excellent steam coal.

In the Central City road, ½ mile east of Hillside, No. 11 coal has been opened at an elevation of 500 feet. the following section was made on the hill and the face of the opening:

Section ½ Mile East of Hillside.

	Feet.	Inches.
Shale	25	
Coal (No. 12)	3	
Clay	1	
Limestone	2	
Clay	0	8 to 10
Coal	1	5
Clay parting	0	1
Coal	2	6
Blue band		2
Coal (bottom not seen)	1	2
Covered	7	
Sandstone	15	

In the narrow strip of land along the northern boundary of the quadrangle between Hillside and Bevier, No. 11 coal has been opened in six or eight places. Some of the openings are closed permanently and abandoned, and others are operated for local trade, and are open only part of the year. Some small openings for local use have been made on No. 11 west of Hillside and the coal either worked out or abandoned.

SUNRISE MINE.

The Sunrise mine is located on the west side of the railroad between Elk Valley and Bevier. The mine was operated on No. 11 coal. The elevation of the coal is about 490 feet. The coal is so near the crest of the hill that it has not been profitable to operate the mine owing

to dirt slips and breaks in the top. A number of attempts to operate the mine have failed. A section at the mouth of the mine shows 86 inches of coal with a 2-inch clay parting 30 inches from the bottom.

DRAKESBORO REGION.

The shaft at the Black Diamond mine at Drakesboro was first sunk to No. 11 coal, which was worked for some time, and later sunk to No. 9, which is the coal now worked there. No. 11 coal was found at a depth of 46 feet below the surface, and 86 feet above No. 9.

About one mile east of Drakesboro, a short distance east of the Diamond Block mine, No. 11 coal has been opened by drift at an elevation of 417 feet.

A few yards north of the Drakesboro quadrangle and one-half mile west of the northeast corner, No. 11 coal is worked on John Robert Casebier's land at an elevation of 480 feet, or 63 feet higher than at the opening just east of Diamond Block mine. The dip in the Casebier mine is south 65 degrees west.

Section at Casebier Mine.

	Feet.	Inches.
Coal (No. 12)	4	
Gray shale	4	
Limestone	4	
Clay	0	2 to 8
Coal	1	6
Clay parting		½
Coal	2	3
Blue band		2
Coal	1	6
Fire clay.		

BEECH CREEK REGION.

No. 11 coal at Beech Creek is only about 50 feet above No. 9. The No. 11 coal was originally worked there, but was later abandoned for the No. 9 bed. It is reported that the No. 11 coal in some of the rooms reached a thickness of 9 feet 10 inches, which is perhaps the thickest deposit of this coal in the Western Kentucky field. The elevation of the coal is about 470 feet. At a point one mile west the same coal is at an elevation of 460 feet.

At Thomas Casebier's opening, one mile north of Beech Creek mine, No. 11 coal is at an elevation of 540 feet.

Section at Thomas Casebier's Mine.

	Feet.	Inches.
Coal No. 12—not all seen	2	
Shale	4	
Black slate, hard	5	
Coal	1	6
Clay parting	0	½
Coal	2	2
Blue band	0	2
Coal	1	9

About $1\frac{1}{4}$ miles southwest of Beech Creek mine No. 11 coal has been opened at an elevation of 560 feet. It is up near the crest of the hill, where more or less difficulty will be experienced with the roof. The following measurement was made at the face of the coal:

Section in Opening $1\frac{1}{4}$ Miles Southwest of Beech Creek Mine.

	Feet.	Inches.
Top coal	1	6
Clay parting		1
Coal	2	7½
Blue band		3
Coal	3	1½
Total	7	7

On Mr. J. A. Gray's land, $1\frac{1}{2}$ miles west of Beech Creek mine, No. 11 coal is opened at an elevation of 480 feet. The following is a section at the mouth of the mine:

Section at J. A. Gray's Opening.

	Feet.	Inches.
Black slate	1	
Coal	1	6
Clay parting		½
Coal	3	
Blue band		2½
Coal	1	11
Coal not taken up, about		10

J. W. DUKE'S COAL BANK.

A short distance west of Pond Creek, and one-fourth of a mile south of the Rochester road, No. 11 coal has been opened and operated for local trade on the J. W. Duke land. The elevation of the coal is about 440 feet. The mine is opened by drift and the coal loaded directly into wagons from the tipple. The limestone above the coal is badly broken by crevices. From 6 inches to 3 feet of shale intervenes between the coal and overlying limestone and forms a very treacherous and dangerous roof.

Section at Duke's Mine.

	Feet.	Inches.
Limestone	3	
Gray to black shale ....6″ to	3	
Coal	1	6
Clay parting	0	½
Coal	2	3½
Blue band		2
Coal	2	

MATHIS' OPENING.

About one mile below where the Rochester road crosses Pond Creek and on the east side of the stream, No. 11 coal has been opened on the William Mathis place, at an elevation of 430 feet, or 30 feet above low water in the creek. At the mouth of the opening the coal has 2 feet of limestone above with 15 inches of shale between. The opening was full of water and no measurements of the coal were made.

BROWNING COAL BANK.

No. 11 coal has been opened on the north side of Caney Creek at a point one-half mile above where Caney joins Pond Creek. The elevation of the coal is 460 feet.

Section at Browning Coal Bank.

	Feet.	Inches.
Heavy bedded sandstone	20	
Covered	40	
Coal No. 12	4	
Shale	3	
Limestone	1	3
Shale		8
Coal	4	
Blue band		2
Coal	2	

No. 12 Coal.

No. 12 coal lies close above the limestone which forms the roof of No. 11 coal. Throughout this quadrangle the variation in the thickness of the limestone is small. There is invariably a shale below the limestone which may vary from 3 inches to 4 feet in thickness. Above the limestone is a shale bed that may vary from 10 inches to as many feet, so the interval between coals 11 and 12 may be 3 or 4 feet or it may be 15 to 20 feet. The average interval is 4 feet in the western part of the quadrangle and 10 feet or more in the eastern part. At Paradise on Green River the interval between the two coals is 17 to 20 feet.

At no place in the Drakesboro quadrangle is the No. 12 coal worked either as a local or commercial proposition. The only place where it has ever been worked to the writer's knowledge was in the Black Diamond shaft at Drakesboro. It was worked there in connection with No. 11 coal for a short period of time.

The coal is unreliable in thickness and in many places it is less than two feet in thickness. The top is a soft rotten shale which will not stand even in narrow workings without practically solid timbering.

MINING AND MINING METHODS.

The shipping mines of the Drakesboro quadrangle are all supplied with modern equipment. Some type of undercut puncher or chain machine is used in all of the mines. With one or two exceptions the mines are all equipped with motor haulage and electric light on the main haulage ways. Wooden end-dump cars which

hold up to two tons are in universal use. At the shaft mines automatic dump cages are in use and the coal is dumped on the screens which convey it to the railroad cars. In passing over the screens the coal is graded into a number of different sizes to suit the requirements of the trade, and each size is diverted to a separate car. None of the coal is washed.

Some modification of the room and pillar method in mining is in general practice. In mining No. 9 coal from 33 to 45 per cent. of the coal is left in the mine. In exceptional cases perhaps 75 per cent. of the coal is recovered, but the general average of coal recovered is more nearly 55 per cent. Under present conditions, when viewed from the standpoint of the operator, there is some justification in such a wasteful practice, but when we consider this stored-up energy as a heritage of this and future generations and the fact that, when once exhausted, it can never be replaced, such a waste and wanton destruction of the coals of this and other coal-producing States is criminal. The public demands a cheap fuel and the operators, in a fierce competition, have but one option in the matter, viz., to produce a large tonnage at a small profit. To meet such requirements the item of cost and production must be kept at a minimum. Under present conditions this apparently does not permit the extra expense of pulling pillars and working out areas that are near the outcrop or difficult of access.

The president of one of the large companies of Western Kentucky is authority for the statement that they did not make any profit out of the coal itself; that it took the entire price received for the coal to pay for the mining, interest on the investment, and overhead expenses, and the only profit received was from the rent of houses and from the commissary. Such a condition, however, may not be so bad for the coal operator as might be expected from such a statement, where one or two small mines are made to produce a sufficient revenue to pay the overhead expenses of the mine and interest on ten, fifteen or twenty thousand acres of coal land that was bought at an extremely low price and is constantly increasing in value.

COMPOSITION OF COAL.

Analyses of coals from the Western Kentucky field will be found in Series IV., Vol. II., Part I., Kentucky Geological Survey Reports.

The quality of a coal should determine its value. In the early history of the coal mining industry the analysis of coals was looked upon more as a matter of scientific interest than as a basis for determining the commercial value of the coal. The heating power or calorific value of a coal is the result of the complete oxidation or burning of all of the combustible elements in the coal. The impurities are the non-combustible elements, such as sulphur, ash and moisture. The sulphur, however, possesses some heating value.

The calorific value is expressed as "Calories," or as British Thermal Units (B. T. U.), being respectively the number of Calories or British Thermal Units produced by one pound of the coal.

A Calorie is the amount of heat required to raise one kilogram of water one degree Centigrade, and a British Thermal Unit the amount of heat required to raise one pound of water one degree Fahrenheit, the water being at the temperature where its density is greatest.

Two methods are in common use in analyzing coals. These are the proximate method and the ultimate method. In the proximate analysis the amounts of moisture, volatile matter, fixed carbon, ash and sulphur are determined. In the ultimate analysis the amounts of moisture, ash, sulphur and the constituent elements, which constitute the organic substances, such as hydrogen, carbon, nitrogen and oxygen, are determined.

Where no burning tests have been made of coals the best guide to their relative heating values is to be found in the B. t. u., as expressed in the analyses. A coal having 11,000 B. t. u. per pound would have 22 million heat units per ton. At $3.00 a ton the consumer pays 13.63 cents per million units. A coal having 13,000 B. t. u. per pound and retailing for $3.50 per ton costs the consumer 13.46 per million units. It is evident, therefore, that a coal with 13,000 B. t. u. per pound is cheaper

at $3.50 a ton than a coal with 11,000 B. t. u. per pound is at $3.00 a ton.

A large percentage of the coals now used by the U. S. Government is purchased on the basis of their heating value as shown by chemical analysis. Some of the advantages derived from the purchase of coals on the basis of their heating value are summarized in Bulletin No. 339, U. S. Geological Survey, from which report the following is taken:

"When the bidder is allowed to specify the quality of the coal he proposes to furnish as determined by a chemical analysis, he is placed on a strictly competitive basis with other bidders. * * * This furnishes a basis for settling disputes regarding the quality of the coal delivered and the price to be paid if the fuel is either better or poorer than has been guaranteed. * * * The purchase of coal under a contract on the basis of quality stimulates the operator to make a better preparation of the coal before it is shipped to market. * * *

"The aim in the purchase of coal for any power plant should be to obtain a fuel which will produce a horse-power for the least cost, all things being considered, such as the equipment, the price of coal, and the cost of labor and repairs. Experiments have been made which seem to indicate that almost any fuel may be burned with reasonable efficiency in a properly designed apparatus. The recognized requirements are as follows:

"A supply of fuel fed to the furnace as uniformly and continuously as possible.

"An air supply slightly in excess of the theoretical amount required for complete combustion.

"A sufficiently high temperature to ignite the gases which are driven off from the fuel.

"A complete mixture of these gases with the air supplied before they reach a cooling surface, such as the shell or tubes of a boiler.

"Some of the factors which may influence the commercial results obtained in a boiler are the cost of the coal, as determined by price and heating value; care in firing; design of the furnace and boiler setting, size of grate, etc.; formation of excessive amounts of clinker

and ash; draft available; size of the coal (uniformity of size is desirable).

"When coal is mined it contains moisture to a greater or less extent. It is exposed to the air in shipment and may either dry out or be drenched by rain. The moisture in the coal delivered is worthless to the purchaser, and really costs him a considerable amount in freight and cartage, and in the loss of the heat absorbed during its evaporation in the furnace. * * * Under present conditions the moisture is an important element in the valuation of a ton of coal. It is evidently necessary to consider the coal just as it is received in order to determine its value to the consumer, but chemical reports should be made on the basis of both the 'dry coal' and the 'coal as received.' The dry-coal basis is convenient for comparing several coals in regard to the relation of each element to the others; this is important because the moisture in the same coal varies from day to day. The dry coal basis is also convenient for comparing the performance of boilers when burning the same or similar coals. Of several coals having a similar composition the one which has the least moisture and the least ash will generate the most steam when burned under a boiler.

"Ash is made up of earthy matter and other impurities which will not burn. In commercial coals its proportion may range from 4 to 25 per cent. Coals containing small percentages of ash are most valuable, not only because of their correspondingly higher heating capacity, but because there is less resistance to the free and uniform distribution of air through the bed of coal. * * *

"The volatile part of coal as shown by the analysis may in some coals be all combustible, but it generally contains some inert matter. * * *

"Of two coals of different character, the one which contains the higher proportion of fixed carbon is most easily burned so as to give the maximum efficiency. However, if the coal containing the higher volatile matter is properly burned in a suitably designed furnace, it may be made equally efficient.

"Sulphur may be present in the free state, or as is more commonly the case, in combination with iron or other elements. Other impurities with sulphur often form a clinker which shuts out the air and increases the labor of handling the furnaces. It is possible, however, to burn coals containing up to 5 per cent. of sulphur without particular difficulty from clinkers. A little steam introduced under the grate will relieve much of the trouble. * * *

"In general it may be said that in any market the coal obtainable at the lowest price is the most economical, provided the furnace equipment is suitable. If the furnace is not so designed as to permit the use of the cheaper coal, it should be changed.

"The results of tests tend to show that, other conditions being equal, coals of similar composition are of value in proportion to the British thermal units in the coal as received—a basis on which, indeed, all coals may be valued approximately. It should be remembered, however, that the value of a coal for any particular plant is influenced by the fact that all furnaces are not equally suitable for burning the many grades of coal. Aside from this factor, coals may be compared in terms of British thermal units obtained for 1 cent, or on the cost per million heat units.

"In the purchase of coal, then, attention should be given to the character of the furnace equipment and the load; the character of coal best suited to the plant conditions; the number of heat units obtainable for a unit price; the cost of handling the coal and ash; and the possibility of burning the coal without smoke or other objectionable features."

COALS OF THE DUNMOR QUADRANGLE

BY

A. F. CRIDER

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COALS OF THE DUNMOR QUADRANGLE

INTRODUCTION.

The Dunmor quadrangle is one of six quadrangles skirting the southern border of the western coal field on which the writer, during the seasons of 1913 and 1914, has been engaged in a study of the coals and coal-bearing rocks. In pursuing this work three special features have been constantly kept in mind. These are:

1st. Tracing in detail the boundary line between the Pennsylvanian and Mississippian rocks. The base of the pebble-bearing sandstone, where present, has been the division line between the two series. This pebble-bearing sandstone is not always present, however, the line of contact between the two formations being then that of a higher member of the Pennsylvanian.

2d. Accurate outcrop lines of Nos. 9 and 11 coals. While the areas underlain by these coals have been known in a general way, no attempt has been made to delineate the outcrop lines along the southwestern border of the field.

The Dunmor quadrangle marks the point where the outcrop of these coals changes from a general east-west to a north-south direction.

3d. The location and extent of the faults that have in such a striking way affected the stratigraphy, and more especially the outcrop lines and areas of No. 9 and No. 11 coals.

While the above are considered of major importance no less attention has been paid to the economic importance of the coals below No. 9.

To obtain an accurate knowledge of the economic products of a region necessitated a study of the general geology, topography, history of the formation of the strata and their present arrangement or structure.

LOCATION.

The Dunmor quadrangle is located along the southeastern border of the western Kentucky coal field. It is bounded by meridians 86° 45′ and 87° and by parallels 37° and 37° 15′, and includes approximately 238 square miles. The major part of it lies in western Butler County, but it also includes a part of eastern Muhlenberg, northern Logan, and a very small area of southern Ohio County. The town from which the quadrangle derives its name is located near the extreme southern boundary line of Muhlenberg County on the western border of the quadrangle.

PREVIOUS WORK.

The first mention of the geology of this region was made by W. W. Mather, in the First Geological Report on Kentucky, 1838. Mr. Mather was appointed by Governor James Clark "to make a geological reconnoissance of the mineral resources of the State." He made a trip down the Ohio River, stopping at Owensboro and Henderson. Coal was then being mined in Bon Harbor Hills west of Owensboro and at low water at Henderson.

His route from there was up Green River, stopping at Rumsey, at lock and dam No. 2 on Green River. At Vaught's mill, on Pond Creek, in Muhlenberg County, he describes two coals which are evidently Nos. 9 and 11.

The reference made to the area within the Dunmor quadrangle is as follows:

"Another point on the south boundary of the coal field of Green River is near Muddy River" (now Mud River) "on the road from Greenfield" (evidently Greenville) "to Bowling Green."

In Volume I. of the Owen Survey, page 141, Doctor David Dale Owen gives a section of the bluff at the old Mud River mine. A section of a test hole at Williams' landing on Green River below Rochester is also given.

In Volume IV. of the Owen Survey, Sidney S. Lyon describes the contact between the Pennsylvanian and Mississippian on the waters of Mud River in the region of Harreldsville and Diamond Springs and on Deerlick Creek.

In his annual report of the Inspector of Mines for the year 1895, page 268, Professor C. J. Norwood makes a probable correlation of the Mud River coal with the main Nolin coal, Empire coal, Aberdeen coal, Coal 1-B or Bell coal, Mining City coal, and the main Hawesville coal.

ACKNOWLEDGMENTS.

Well records and other information were furnished the writer by Mr. William Willis, of Rochester.

To Mr. Jack Longest, of Browder, the writer is indebted for logs of test holes north of Rochester. The holes were drilled by Mr. C. S. Arnold, of Penrod, who gave locations of the holes on the map.

TOPOGRAPHY.

The Dunmor quadrangle has a varied type of topography due to the difference in the character of the underlying rocks. On this basis and for convenience of description it may be separated into the Sandstone uplands, the Limestone area, and the Stream valleys.

SANDSTONE UPLANDS.

The Sandstone uplands lie north of a meandering line which begins near the southwestern corner of the quadrangle, extends in a north-northeast direction to the mouth of Forgys Branch, and thence due east to Muddy Creek. It then turns northeast again and leaves the eastern edge of the quadrangle near Hickory Stand school.

South of the above described line, extending from 1 to 5 miles distance, are numerous outliers of a hard pebble-bearing sandstone which caps the tops of isolated hills and ridges which stand out as prominent topographic features of the region. The most prominent of these is Iron Mountain, in the southwestern part of the quadrangle. It rises to an elevation of 700 feet and is surrounded by low lands which are but little above the 400 contour line.

Red Hill school, Harreldsville, Dallam Creek, Cave Spring school, Union school and Alum Spring school

are each located on high sandstone hills or ridges which are outliers of the Sandstone uplands.

North and west of the above described line the country is highest in the southern part with a slope to the north. Near the southern boundary of the sandstone area the crest of the highest hills in the quadrangle is at an elevation of 700 to 760 feet. The highest point in the northwestern part of the quadrangle is 4 miles west of Rochester, where the elevation is 660 feet, giving a general northward slope to the surface of 100 feet in a distance of 10 miles.

The entire area of the Sandstone uplands is eroded by a network of streams the headwaters of which have completely dissected the once level plain and reduced it to a series of serrated ridges with deep-cut valleys between.

That the entire region was originally one level plain with a gradual slope to the north is shown by the fact that Mud River and Muddy Creek, two large streams which head beyond the southern border of the Dunmor quadrangle, have made their way from the Limestone area across the Sandstone uplands to Green River. The softer strata in the Limestone area have been more easily affected by the action of the stream waters and have been more uniformly reduced than the northern part of the quadrangle which has been preserved by reason of the resistant sandstone which comes at the base of the Pennsylvanian.

Mud River, south of the Sandstone uplands, meanders back and forth across a wide flood plain which is not infrequently 1 mile wide. In the sandstone area, from 1 mile below Arnold's bridge to Buchanan ferry, the stream is enclosed between sandstone cliffs which rise from 100 to 200 feet above the river with practically no valley lands.

LIMESTONE AREA.

The Limestone area extends over the southern part of the quadrangle south of the Sandstone uplands. It is underlain by thick deposits of soft shale interbedded with thin beds of limestone. Erosive agencies have attacked these soft materials and reduced the general level of the region to a far greater extent than the sandstone uplands to the north.

The basal sandstone, which forms the southern boundary of the Sandstone uplands, once extended over the greater part if not the entire area of the Limestone area as shown by outliers of this sandstone, which has prevented an even greater reduction than we now find.

The greatest amount of cleared land is to be found along the waters of Muddy Creek and Mud River, in southern Butler and northern Logan Counties.

STREAM VALLEYS.

Green River valley is the largest and most important one of the quadrangle. From the northeastern corner of the quadrangle to a point 2 miles below Mining City it is from ½ to ¾ of a mile wide and is bordered by high sandstone cliffs on either side. Below this it widens out and is from 1 to 2 miles across. The widening of the valley is due to a thick deposit of shales which have yielded more readily to the action of stream waters than the sandstone cliffs in the region of Mining City. About one-half of the area of Green River valley in this quadrangle is still uncleared.

Where the sandstones above No. 9 coal began to come down to the water's edge near Williams Landing, the river valley again narrows and so continues for some distance down the river. The width of the shale outcrop coming between the Mining City coal and No. 9 coal is clearly marked in the Dunmor and Hartford quadrangles by the physiography of the region.

Mud River valley from Rochester to the mouth of Canfield branch is from ¼ to 1 mile wide. From Canfield branch to 1 mile below Arnold's bridge there is practically no valley or bottom land, the high sandstone cliffs extending down to the water's edge. From near Arnold's bridge to the southern edge of the quadrangle the valley again widens from ½ to 1 mile or more.

From Arnold's bridge to the south the action of the stream has been largely spent in degrading the soft shale slope's. From Arnold's bridge to Corum's ferry the course of the stream is at right angles to the strike

of hard sandstones, so that in this region the force of the stream has largely been spent in cutting the main channel.

Muddy Creek valley shows more uniformity in width than any of the larger streams of the quadrangle, but even this stream shows a much wider valley in the Limestone area than in the Sandstone region. A large percentage of the valley from Townsville to the mouth of the stream at Mining City is still uncleared.

Rocky Creek and Wolf Lick Creek, both tributaries to Mud River, have broad fertile valleys, the greater part of which are still in timber.

The above mentioned streams furnish the principal valley lands of the quadrangle, although there are numerous smaller streams that in the aggregate have a large acreage of fertile alluvial valleys.

Could the entire area of the stream valleys of the Dunmor quadrangle be reclaimed and converted into farming land it would add very much to the agricultural wealth of the region. At present, however, only about 15 per cent. of these, the most fertile lands of the region, has been opened to agriculture.

CULTURE.

Farming is the chief pursuit of the people. Broad alluvial valleys of Green River, Mud River, Muddy Creek and their numerous tributaries afford a comparatively large percentage of very fertile farming land. It is only in very recent years, however, that these bottoms have begun to be cleared and put in cultivation; and even now less than one-fourth of the bottom lands are cultivated. It is claimed by some of the largest landowners of this region that the complete reclamation of the Green River and Mud River bottom lands as far south as the southern edge of Butler County is now impossible as a result of the locks and dams in Green River. That the locking and damming of Green River does maintain a higher stage of water and requires a smaller volume of flood water to overflow the lowlands than would be required without the locks and dams there can be no doubt. From a study of the topographic maps,

which show the amount of cleared and wooded lands, from Rochester to 8 miles above Woodbury, it is evident that the greatest area of wooded land on Green River between these two places is just above the Government lock at Rochester.

Less than one per cent. of Mud River bottom in Butler and Muhlenberg Counties has been cleared. If the lock at Rochester was above instead of just below the mouth of Mud River the water in this stream would be so lowered that the entire bottom land could be thoroughly drained. The purpose of placing the lock below the mouth of Mud River was to afford navigation for a distance up Mud River; but since the stream has been practically abandoned for that purpose, the removal of the lock just above the mouth of the stream would open up thousands of acres of valuable agricultural land on Mud River and its tributaries.

There are no commercial coal mines located in this quadrangle. Nos. 9 and 11 coals underlie about 12 square miles in the extreme northwestern corner of the quadrangle where a few small country mines are worked for local trade.

In the region of South Hill, Dunbar and Mining City are four or five small mines which are operated during the fall and winter months.

The old Mud River mine, which at one time was connected by a branch railroad from Penrod and afforded employment for a large number of men, has been abandoned and the railroad track taken up.

The only railroad which touches this area is the Owensboro Branch of the Louisville & Nashville, which enters the quadrangle at Rocky Creek and traverses the southwestern corner of the area for a distance of about 10 miles. From Rocky Creek to Drakesboro the railroad runs approximately parallel to and a short distance west of the western border of the quadrangle. Browder is the nearest railroad shipping point from Rochester. Rockport and Echols, 6 miles north of the quadrangle, are the nearest shipping points to the Illinois Central Railroad.

Green River forms the principal means of transportation for the northern and eastern portions of the quad-

rangle. The river is supplied with locks and dams which maintain a sufficient stage of water for the largest boats to be operated throughout the year. The large packets make regular trips from Evansville to Bowling Green, affording adequate service for the movement of freight. Since the advent of the automobile, however, passenger travel by boat has been reduced to a minimum.

Mud River, during the operation of the Mud River mine, was used as a means of transportation, but in recent years the stream has been allowed to become choked with logs and brush and the only use made of it now is the floating of logs in seasons of high water. Small tracts of the once famous forests of Western Kentucky are still to be found along the waters of Mud River and its tributaries.

The sandy ridge soils of the Pennsylvanian rocks produce an excellent quality of fruit, especially apples. The color and flavor of the apples are such as to command the highest price in any market. More attention should be given this industry, which could be made a profitable one under systematic and concerted action by the landowners.

A fairly good system of public roads is maintained in this region. In the northern part of the quadrangle, where there is little or no limestone at the surface, the roads are all ordinary dirt roads which are kept in fairly good condition by means of the split log drag.

In the southern half of the quadrangle, where the calcareous shales and limestones of the Mississippian rocks come to the surface, crushed limestone is used on many of the public roads.

GENERAL GEOLOGY.

All of the rocks outcropping in the Dunmor quadrangle are of sedimentary origin and belong to the Mississippian and the Pennsylvanian series. Owing to a persistent dip, which in the Dunmor quadrangle is slightly west of north, both series appear at the surface, the Pennsylvanian occupying the northern part, and the Mississippian the southern area of the quadrangle.

MISSISSIPPIAN.

The rocks of Mississippian age are a series of shales, limestones and sandstones. With the exception of the basal sandstone of the Pennsylvanian the sandstones of the Mississippian are harder and more resistant to the weathering agents than the sandstones of the Pennsylvanian series. They are fine grain, gray to white in color, and make excellent building stone for chimneys, foundations, flaggings, and buttresses for bridges, etc. The uppermost sandstone of this series forms the surface of a large part of the hilly region bordering the eastern edge of the quadrangle south of Alum Spring school. It is a fine grain massive sandstone and is often mistaken for the basal sandstone of the Pennsylvanian series. The latter, however, in places contains a large percentage of white quartz pebbles, while the former never has them.

The shales of Mississippian age usually contain a large percentage of calcium carbonate and weather into a red sticky clay, which gives rise to the worst roads of this region. They are frequently found interbedded with thick limestones. The above features readily distinguish the Mississippian shales from those of the Pennsylvanian age.

Sandstones and shales predominate in the upper part of the Mississippian and give rise to a rough type of topography such as is found for a few miles south of the border of the Western Kentucky coal field. Further south, however, the sandstones and shales give place at the surface to limestones, the weathering of which produces the fertile limestone soils of southern Christian, Logan, Todd, and Warren Counties.

PENNSYLVANIAN.

GENERAL DESCRIPTION AND SECTIONS.

The Pennsylvanian rocks form the surface of a little more than one-half of the area of the Dunmor quadrangle. The surface underlain by these rocks lies north and west of a line beginning 1 mile north of the southwestern corner of the quadrangle and extending along

the west side of Wolf Creek and Mud River to a point 1 mile below Arnold's bridge across Mud River. From thence it swings back south near the foot of the hills on the east side of Mud River to near the mouth of Forgy's branch, thence in an easterly direction to Muddy Creek. It follows down the west side of Muddy Creek to about due west of Hickory Stand school, where it crosses over to the east side of the stream and leaves the quadrangle on the east a short distance south of Hickory Stand school.

South and east of the above described line for a maximum distance of 6 miles are numerous outliers of Pennsylvanian rocks which indicate at one time a much more extensive area of these rocks than we find at present. These outliers are capped with the pebble-bearing sandstone which lies at the base of the Pennsylvanian series.

The materials which form the strata of the Pennsylvanian are sandstones, shales, coals, clays and thin limestones. The relationship of the strata are shown in the following general section from the base of the series to a few feet above No. 12 coal.

Generalized Section.

1.	Shale	15
2.	Sandstone (Anvil rock)	30
3.	Shale	35
4.	Coal (No. 12)	4
5.	Soft sandstone and shale	10 to 15
6.	Limestone	3 to 5
7.	Gray slate	0 to 2
8.	Coal (No. 11)	5 to 7
9.	Fire clay and shale	4
10.	Sandstone	7
11.	Gray shale	15
12.	Gray rotten sandstone	20
13.	Coal	thin
14.	Gray shale containing thin sandstones	20
15.	Black slate	2
16.	Coal (No. 9)	5
17.	Fire clay	1
18.	Shale	30
19.	Limestone	1

20.	Shale and sandstone	20
21.	Black slate	3
22.	Shale	25
23.	Black slate	3
24.	Coal	2
25.	Shale	20
26.	Sandstone	30 to 40
27.	Shale	20
28.	Sandstone, cliff-forming	70 to 100
29.	Shale	10 to 20
30.	Rotten limestone containing marine fossils	1
31.	Coal (Mining City)	3
32.	Shale	23
33.	Limestone	2 to 8
34.	Coal	3
35.	Sandstone and shale	20
36.	Siliceous shale	15
37.	Aluminous shale	5
38.	Coal (Dunbar)	3 to 4
39.	Hard siliceous clay containing narrow strap leaves	5
40.	Shale	55
41.	Sandstone, micaceous	40
42.	Coal (Mud river)	3+
43.	Fire clay	3
44.	Dark blue shale	30
45.	Coal	1
46.	Dark blue shale grading downward into siliceous slate or shaly sandstone	40
47.	Soft, red-weathering sandstone containing bands of iron ore	80
48.	Shale intercalated with thin sandstones	160
49.	Coal	2
50.	Fine grain stratified sandstone containing small quartz pebbles	5 to 20
51.	Coal	2 to 3
52.	Shale	10 to 20
53.	Coarse-grain massive sandstone studded in places with quartz pebbles	0 to 140
54.	Dark blue calcareous shale	5
55.	Coal (Chester age)	1+
56.	Limestone.	
		937 to 1161

The above section is a composite one made up principally from surface outcrops in different parts of the quadrangle. The lower part, from the top of the Chester to Mud River coal, was made from exposures between Forgy's mill and Mud River mine. That part included between Mud River coal and the Dunbar coal (the equivalent of the Mannington coal) was made from surface outcrops in the region between Mud River mine and Ward's school house. The interval between the Dunbar coal and for 165 feet above the Mining City coal was made of exposures between Dunbar and Mining City. The remainder of the section was obtained from the region north and west of Rochester, where coals 9, 11, and 12 are well exposed at the surface.

The entire thickness of the Pennsylvanian rocks exposed, as shown in the section, is from 937 to 1,161 feet. Of this amount 181 feet is above No. 9 coal.

The interval between No. 9 coal and the Dunbar coal is from 307 to 363 feet.

The interval between the Dunbar coal and the base of the Pennsylvanian series in this quadrangle is 436 to 602 feet. The increase and decrease in thickness in this interval is largely due to the thickening and thinning of the basal pebble-bearing sandstone, which in places is 140 feet thick, and again may be entirely absent.

A coarse pebble-bearing sandstone forms the basal member of the Pennsylvanian series. In most of the literature of the State Geological Survey it is known as the conglomerate sandstone.

It is composed of two divisions with a 10 to 20-foot shale interval between. The lower member varies from 30 feet to as much as 140 feet in thickness and in places may be entirely absent, the lowest member of the Pennsylvanian being a carbonaceous shale. The upper sandstone member varies from 5 feet to 40 feet. The lower member is a coarse-grain sandstone which is highly cross bedded and contains irregular bands of iron ore. It rarely shows any regular stratification lines. It weathers irregularly and forms the most rugged type of topography found in the Western Kentucky coal field. In some places the lower part of the sandstone is a mass of quartz pebbles barely cemented with a siliceous water-

worn sand. Some of the pebbles are as much as 2 inches in diameter. In the upper part the pebbles occur in irregular bands. In places the entire sandstone carries very few or no pebbles at all.

The upper member is a finer-grain, stratified sandstone which carries a few scattering quartz pebbles which range in size up to ½ inch in diameter. In Edmonson and Grayson Counties it is known as the Bee Spring sandstone.

At Diamond Springs Hotel, which is located on the waters of Rawhide Creek, just off the Dunmor quadrangle, the elevation of the base of the sandstone is 450 feet. North of Rector's bridge, near the boundary line between Butler and Muhlenberg Counties, the base of the sandstone is at an elevation of 530 feet. The sandstone at the latter place does not carry any pebbles. Further east, however, at Harreldsville, and on the Bowling Green road at Forgy's mill, on Mud River, the basal sandstone carries an abundance of quartz pebbles, some of which are as much as 2 inches in diameter.

Close above the lower or basal sandstone is a thin coal which has been opened in a number of places, but rarely attains the thickness of a workable coal. It occurs in a bed of shales which is from 10 to 20 feet thick. This is at the same horizon as the Nolin coal of Edmonson and Grayson Counties. It is a very persistent coal, and has been opened in a number of places in the Dunmor quadrangle.

It has been opened on Sam Dearmond's place, 1 mile southeast of Dunmor, at an elevation of 590 feet, where it is only 5 feet above the top of the basal sandstone. Where opened it was only 1½ feet thick.

The same coal has been opened on G. G. Logan's place, ¾ of a mile northeast of the Dearmond opening. It is reported to be 22 inches thick.

One mile southwest of Mt. Moriah Church the same coal outcrops in the Dunmor road at an elevation of 560 feet. The upper pebble-bearing sandstone at this place has apparently given place to a shaly sandstone, as the following section indicates:

Section in Road 1 Mile Southwest of Mt. Moriah Church.

	Feet.
Shale	30
Shaly sandstone	10
Coal	thin
Shale	10
Sandstone top of basal sandstone.	

At Forgy's mill the base of the pebble-bearing sandstone is at an elevation of 480 feet. The pebble-bearing sandstone rests on a blue Chester shale, with a white siliceous limestone below. The following is a section of the contact:

Section at Forgy's Mill.

	Feet.
Pebble-bearing sandstone	80
Blue Chester shale	5
Pure white siliceous limestone	thin
Blue shale	15
Blue limestone.	

On the north side of Forgy's branch the base of the pebble-bearing sandstone has dropped to 425 feet elevation, or 55 feet lower than it is on the south side of the branch. Just north of Forgy's branch the bipartite character of the pebble-bearing sandstone is shown in the following section:

Section of Hill North of Forgy's Branch.

	Feet.
Stratified sandstone containing numerous small quartz pebbles	40
Shale	15 to 20
Basal pebble-bearing sandstone	140

The basal sandstone at the above mentioned place attains the greatest thickness of any place observed in the quadrangle. The upper sandstone carries a large percentage of pebbles which rarely attain ½ inch in diameter. It differs from the lower sandstone in being stratified, is less cross-bedded, and contains small pits of clay which are never present in the basal member.

The point where the above section was made is in a deeply channeled basin which was made into the Chester rocks and subsequently filled with the basal member of the Pennsylvanian. At a point 1 mile east of where the last section was made the contact between the basal Pennsylvanian and top of the Mississippian rocks is at an elevation of 540 feet, or 115 feet higher than it is at the place where the last section was made.

The basal sandstone of the Pennsylvanian thins to the east and finally disappears entirely at the eastern edge of the quadrangle. In the region of Townsville the basal sandstone has thinned to 60 feet and the upper member has thinned to 5 feet, as the following section on the Bowling Green road, 1 mile northwest of Townsville, will show:

Section 1 Mile Northwest of Townsville.

	Feet.
Shale.	
Sandstone containing small quartz pebbles	5
Clay	2
Coal	2
Shale	20
Basal pebble-bearing sandstone	60
Limestone of Chester age.	

As will be seen from the above the two sandstones have thinned perceptibly to what they are on Forgy's branch, but the shale interval between them remains constant.

A thin coal, which corresponds to the position of the Nolin coal, is present near the top of the shale bed 20 feet above the basal sandstone. This coal is at the same geological horizon as the one which has been opened on Sam Dearmond's place, 1 mile south of Dunmor, and 1 mile southwest of Mt. Moriah Church.

In the region of Alum Spring school the basal sandstone of the Pennsylvanian is entirely absent. What appears to be the top of the Chester is at an elevation of 550 feet. A carbonaceous shale forms the basal member of the Pennsylvanian at this point. A coal 36 inches thick occurs in the shale 25 feet above the top of the Chester. It has a shale roof and what appears to be an excellent grade of fire clay floor. The upper half of the coal is of fair quality, while the lower half is rash that is discarded in mining.

The second coal above the basal sandstone occurs near the base of the thick deposit of shale which is given in the general section as 160 feet thick. It was observed in the railroad cut a short distance south of Penrod, and again at the M. H. Simmons place, 1 mile northwest of Mt. Moriah Church. At the latter place it was worked in early days and the coal hauled to Hopkinsville. It is reported to be 22 inches thick under a shale roof and has a clay floor. The elevation of the coal at the Simmons place is approximately 480 feet. This is the upper Nolin coal or the one which comes close above the Bee Spring sandstone.

MUD RIVER COAL.

The next coal of any importance above the basal sandstone in this region is known as the Mud River coal. Its position in the geologic section of Western Kentucky has been commented on by Owen and Norwood in former reports of the Geological Survey. Owen, in Vol. I., Old Series, page 140, describes it under the name of "Roberts coal" or "Main coal" of "Muddy River," and correlates it with the thin coal 26 feet 10 inches above the bottom of the drill hole in the Airdrie shaft section. The distance between the Mud River coal and No. 9 coal in his section is about 530 feet.

In the same report, page 143, Doctor Owen correlates the coal at the bottom of the Williams Landing section with the Mud River coal. This correlation is erroneous, as the top of the bore hole at Williams Landing began about 30 feet below No. 9 coal, making the distance between No. 9 coal and Mud River coal in this correlation only 122 feet. His first correlation was nearer correct.

Mr. C. J. Norwood, in Mine Inspector's report for the years 1901 and 1902, page 324, correlates the Mud River coal with coal 1-B, or Bell coal; "the main coal formerly worked at Hawesville;" the "Main Nolin" coal of Edmonson County; Empire coal; Aberdeen coal, and Mining City coal. The Bell coal, the Nolin coal and the main Hawesville coal are doubtless at the same geological horizon and belong in the bed of shales close above the top of the basal pebble-bearing sandstone. The Empire coal outcrops in the high hill just west of Ward's bridge across Rocky Creek at a point 100 feet above an opening on the Mud River coal.

The Mining City coal, which Mr. Norwood correlates with the Mud River coal, is 90 to 100 feet above the Empire coal, or about 200 feet above the Mud River coal.

The Aberdeen coal is the only one of the six coals, which Mr. Norwood correlates with the Mud River coal, that the present writer was able to verify.

The Mud River coal was formed in basins which were more or less local in their distribution or else the coal has been removed by erosion over large areas subsequent to its accumulation. It is more probable that the latter explanation is the correct one, as shown by the nature of the coal and overlying sandstone at Mud River and Aberdeen. It is at least true that the coal has been greatly eroded subsequent to its formation.

At the old Mud River mine the coal at the mouth of the old entry and for a short distance in the hill has a dark shale roof which is filled with well-preserved fossil plants. Further in, however, the shale roof is entirely cut out and the overlying sandstone, which forms a steep cliff above the coal, forms the roof of the coal. Still further in the sandstone has cut the coal down too thin to be profitably worked and in places it is entirely absent. At the Aberdeen mine on Green River the sandstone cuts out the coal entirely.

West of the Dunmor quadrangle the Mud River coal is either very thin or entirely absent. It assumes its greatest development in the region of the old Mud River mine and to the east.

At the old Aberdeen mine on Green River it was worked for a number of years, but is now worked out and the mine abandoned.

Dr. James H. Gardner, former assistant geologist of the State Geological Survey, in an unpublished report on the Elm Lick coal of Ohio County, correlates the Aberdeen coal with the Elm Lick coal. The latter, he says, is the Deanfield coal of Hancock and Daviess Counties.

The Mud River coal is separable into an upper and lower bench which differ materially in their structure

and quality. The upper bench is 10 to 12 inches in thickness and has horizontal lines along which the coal has a tendency to break. It is a much softer coal than the lower bench and soils the hands in handling. The lower bench is a hard block coal with a satin luster and can be handled without soiling the hands. The lines of cleavage are at right angles to the upper bench and the coal comes out in large rectangular blocks. The lower 3 to 6 inches of the seam are rash or bone. A section at the face of the coal in one of the workings of the Mud River mine was measured with the following result:

Section in Mud River Mine.

	Feet.	Inches.
Dark slate roof.		
Coal, soft		10½
Black, brittle shiny coal	2	7
Rash		3
Clay floor.		

In quality the Mud River coal has always been considered one of the best steam coals of this region, and would doubtless make an excellent quality of coke. A sample of the coal collected by the writer and analyzed by J. S. McHargue in the laboratory of the Kentucky Geological Survey gave the following result:

Analysis of Mud River Coal.

Laboratory No. G-3670.

	As received.	Air dried.
Moisture	10.60	4.18
Volatile matter	34.80	37.30
Fixed carbon	49.70	53.27
Ash	4.90	5.25
	100.00	100.00
Sulphur	1.36	1.46
B. t. u.	12410	13303

DUNBAR COAL.

The first coal of any importance above the Mud River coal is known as the Dunbar coal, and is here correlated with the Mannington, Empire and Dawson Springs coal. It occurs about 100 feet above the Mud River coal just described, and 80 to 90 feet below the Mining City coal, next to be described. It has been opened near the top of the high hill ¾ of a mile west of Ward's bridge across Rocky Creek, where its relation to the Mud River coal is shown in the following section:

Section ¾ Mile West of Ward's Bridge.

	Feet.	Inches.
Limestone capping top of hill.		
Shale	40	
Coal (Mannington or Dunbar)	4	4
Shale intercalated with thin sandstones	73	
Sandstone	30	
Coal (Mud river)	3	6
Fire clay	½' to 3	

The Dunbar coal is opened in a number of places in the hills south and east of Ward's school, and is used for local consumption. The elevation of the coal in the above section is 510 feet.

HATCHER MINE.

Mr. T. E. Hatcher has a small country mine opened on the Dunbar coal ¼ mile north of Dunbar Postoffice. The elevation of the coal is 490 feet. The thickness of the coal is quite regular, varying from 4 feet to 4 feet 7 inches. The immediate roof is a dark draw slate 2 inches in thickness, which comes down with every shot. Overlying the draw slate is a firm dark slate or shale which requires very little timber in the rooms and entries. The floor is a very hard, gray siliceous clay which contains impressions of narrow strap leaves.

The limestone which occurs 35 to 45 feet above this coal in the Nortonville and Dawson Springs quadrangles is here 60 feet above, but at the Smith mine, 1¼ mile west of the Hatcher mine, it is only 40 feet above the coal. The following is a section of the hill at the Hatcher mine:

Section at Hatcher Mine, Dunbar.

	Feet.	Inches.
Limestone	2	
Coal reported to be	3	
Shale	32	
Sandstone	20	
Shale	5	
Draw slate		2
Top bench, soft coal	1	10
Soft rashy coal		1
Hard Coal	2	8
Hard fire clay.		

On the south side of the hill from the Hatcher mine is an old opening on a coal just below the limestone. Mr. Hatcher reports that the coal was 3 feet in thickness. This is at the horizon of the Cates coal as described in the report on the Nortonville quadrangle.

A sample of the Dunbar coal from the Hatcher mine collected by the writer and analyzed by Mr. J. S. McHargue in the laboratory of the Kentucky Geological Survey gave the following results:

Analysis of Dunbar Coal.

Laboratory No. G-3668.

	As received.	Air dried.
Moisture	11.43	3.53
Volatile matter	35.67	38.86
Fixed carbon	49.39	53.79
Ash	3.51	3.82
	100.00	100.00
Sulphur	1.54	1.68
B. t. u.	12690	13827

The above analysis shows this to be an excellent coal for domestic and steam purposes and would doubtless make a coke suitable for blast furnace use.

The thickness of the coal together with the cheapness of production and its excellent quality make it one of the most desirable coals in this region. It underlies a large territory and with the exception of No. 9 coal is one of the most reliable coals of Western Kentucky.

Lack of transportation is doubtless the only thing that has prevented its development on a commercial basis.

A shaft at Dixons Landing or Mining City on Green River would reach the Dunbar coal at something less than 100 feet. The location of the shaft at either of the above mentioned places would have the advantage of river transportation, and the coal could be worked up the dip, which would be a great advantage in handling the water. The coal is not as reliable in thickness as No. 9 coal, and for that reason test holes should precede the sinking of a shaft.

SMITH MINE.

The Dunbar coal is also being operated on the west side of Muddy Creek at the H. N. Smith mine. The elevation of the coal is the same as the Hatcher opening, or 490 feet. The general conditions, including the thin limestone in the hill above the coal, are very similar to those at the Hatcher mine. At the Smith opening, however, the limestone is 20 feet nearer the coal than at the Hatcher mine. The following is a section at the face of the coal where a sample was taken for analysis:

Section in Smith Mine.

	Feet.	Inches.
Hard shale roof.		
Draw slate		2
Hard black coal	2	4½
Hard brittle coal	1	9½
Rash		½
Very hard clay floor.		
Total thickness of coal	4	2½

The fire clay below the coal contains impressions of small ferns and narrow strap leaves. No impressions were found in the shale above the coal.

The following is the analysis of the Smith coal made by Mr. J. S. McHargue in the laboratory of the Kentucky Geological Survey from a sample collected by the writer.

Analysis of Dunbar Coal From H. N. Smith Mine.

Laboratory No. 3669.

	As received.	Air dried.
Moisture	11.61	3.81
Volatile matter	35.43	38.56
Fixed carbon	48.59	52.87
Ash	4.37	4.76
	100.00	100.00
Sulphur	1.62	1.76
B. t. u.	12670	13786

BRADLEY MINE.

The Dunbar coal is now being worked at the Bradley mine, ¾ mile north of South Hill on the east side of Hickory Camp Creek. The elevation of the opening is 510 feet, or 20 feet higher than the same coal at the Smith and Hatcher mines.

The Bradley mine was the first place in this part of the quadrangle where this coal was examined and its geological horizon was not determined until after the limestone above the Smith mine was discovered. No limestone was seen in the hill above the coal opening, but it is doubtless present. The coal at the face of the entry is very similar to that in the Smith and Hatcher mines, as the following section will show:

Section of Dunbar Coal in Bradley Mine.

	Inches.
Hard shale roof.	
Draw slate, in places bone coal	2
Coal, top bench, soft	11
Coal, brittle	10½
Rashy coal	4½
Coal, bottom bench	11
	39

The floor of the coal is a hard fire clay which contains narrow strap leaf impressions similar to those found in the basal clay of the Smith and Hatcher mines.

For a distance of 90 feet above the coal the slope of the hill indicates a shale formation. Above the shale comes a cliff-forming sandstone which attains a thickness of 80 feet or more.

A coarse heavy bedded sandstone 30 feet thick or more outcrops in the branch below the level of the coal.

A few abandoned openings on what appears to be the Dunbar coal occur on Panther Creek in the region of Fairview school and between Panther Creek and Rochester. The thin limestone which occurs in the road at Fairview school at an elevation of 510 feet is probably the limestone which occurs 40 to 60 feet above the Dunbar coal. The old openings on the coal in this region show the coal to be 6 to 12 inches thinner than it is at Dunbar and South Hill.

MINING CITY COAL.

Mining City is now scarcely more than a ferry landing on Green River at the mouth of Muddy Creek. Just back of the place on the west side of Muddy Creek in the early days of steamboat traffic on Green River was a coal mine which was worked on an extensive basis. Small tram roads were built from the different openings around the hill to the landing and the coal was loaded in barges for shipment. Only one or two small openings now remain. These supply coal for local trade only.

The coal has not been opened to the writer's knowledge west of Hickory Camp Creek. East of Mining City in the region north of Morgantown it is worked extensively for local trade.

What appears to be the same coal was reached in a diamond drill hole at Rochester at a depth of 60½ feet. The following record of the hole was furnished the writer by Mr. William Willis, of Rochester. The elevation of the top of the hole is about 420 feet.

Core Hole at Rochester.

	Feet.	Inches.
Soil	8	
Sandstone, soft	30	
Shale	20	
Hard limestone	2	6
Coal (Mining City)	3	6
Sandstone	80	
Coal	3	6
	147	6

Another coal is reported to have been struck at a depth of 200 feet.

The coal at Mining City occurs at an elevation of 440 feet close under a heavy coarse sandstone which in this region is from 70 to 100 feet thick. The sandstone forms steep cliffs in the region of Mining City. The narrow valley of Green River in this immediate vicinity is due to the presence and resistant nature of this thick sandstone.

Between the thick sandstone and the coal is a shale which is 10 to 20 feet thick. At the base of the shale and forming the immediate roof of the coal is a thin limestone which is filled with marine fossils. In penetrating this limestone in the core hole at Rochester it was found to be a compact hard limestone. In the mines, however, it is usually nothing more than a rotten marl. The fossils found in this material are badly macerated and it is only occasionally that a perfect specimen is obtained. This calcareous marl with its contents of broken and crushed shells is so characteristic that it becomes an unfailing guide in the determination of this particular coal.

No. 9 Coal.

The next workable coal above the Mining City coal is No. 9 coal. The latter, as shown in the general section, is 236 to 286 feet above the Mining City coal. The shale interval, No. 25 of the general section, with a thickness of 20 feet, was only estimated and is subject to modification.

The area underlain by No. 9 coal in the Dunmor quadrangle comprises approximately 10 square miles. About 8 square miles lie west of Green river in the extreme northwestern corner of the quadrangle, and about 2 square miles in the triangular area north of Rochester along the northern boundary of the quadrangle. The coal in the Green River bottom between the two areas has been cut out by the river, as shown in bore hole No. 3.

A series of bore holes north of Rochester, some of which were begun above and some below the outcrop of 9 coal, assist in determining the area underlain by No. 9 coal. The wells were drilled by S. C. Arnold, of Penrod, for the W. A. Wickliffe Coal Company, and records furnished the writer by Mr. Jack Longest, of Browder. Holes Nos. 1, 3, 4, and 6 are located on the Dunmor quadrangle, and Nos. 2, 5, and 7 are about 1 mile north on the Hartford quadrangle.

Bore Records.

Bore Hole No. 1, J. P. Shrum Tract.

	Feet.	Inches.
Red sandy clay	30	
Hard blue sandy clay	27	
Gravel bed and wash	12	6
Coal	0	2
Fire clay	0	4
Soft porous sandstone	24	
Hard gray sandstone	2	
Gray sandstone and slate	2	
Coal	2	9
Fire clay	0	3
Total	101	

The above well was begun in the edge of Green River bottom below the level of No. 9 coal.

Bore Hole No. 2, on Q. M. Benton Tract.

	Feet.	Inches.
Top surface	27	
Gray sandstone	19	
Hard sandy shale	12	
Gray slate	20	
Black slate	1	4
Coal (No. 9)	4	6
Fire clay, hard	0	5
Hard flinty stone	0	6
Total	84	9

Bore hole No. 2 is located ½ mile south of Wysox, in Spur Creek bottom, and was evidently begun only a few feet below the level of No. 11 coal.

Bore hole No. 3, which is located in Green River bottom, ½ mile northeast of Williams Landing, was drilled to a depth of 68 feet and abandoned on account of a bed of river gravel.

Bore Hole No. 4, R. W. Brown Tract.

	Feet.	Inches.
Sand and gravel	4	
Soft slate	8	
Soft porous red sandstone	32	
Small showing of coal.		
Soft porous red sandstone	12	
Small showing of coal	0	3
Gray sandstone	21	
Sand shale and kidney rock	31	
Gray slate	4	
Black slate	2	
Coal	1	1
Black muck	1	6
Sandstone, gray, very hard	13	
Glass sandstone	8	6
Gray and brown sandstone, hard	3	
Total	141	4

Bore hole No. 4 is located on the R. W. Brown tract in the edge of the bottom, ¼ mile northeast of bore hole No. 3. The hole was abandoned on account of losing the bit in the hole. The top of the hole began near the level of No. 9 coal. The coal 1 foot 1 inch under two feet of black slate at a depth of 114 feet 3 inches is evidently No. 8 coal.

Bore Hole No. 5, Located ¾ Mile South of Wysox, on the J. N. Berryman Tract.

		Feet.	Inches.
Sand and clay		23	
Soft sandstone and slate		13	
Limestone		3	
Gray slate		0	6
Coal, small parting 1 ft. 6 in. from roof	No. 11	4	3
Parting	No. 11	0	3
Coal	No. 11	1	
Fire clay		4	
Gray sandstone		7	
Coal		0	3
Gray slate		15	9
Black slate		0	3
Coal		1	2
Fire clay, black mucky		1	7
Sandstone and slate		13	
Coal		0	3
Sandstone, hard, gray		1	2
Sandstone and slate—½ inch of stone to 6 inches of slate		16	8
Black slate, very hard		2	7
Coal, No. 9		4	7
Fire clay		0	9
		114	

Bore Hole No. 6, on A. O. Berryman Tract, 2 Miles North of Rochester.

	Feet.	Inches.
Clay and gravel	11	
Sandstone, soft porous	6	
Gravel bed, limestone (?)	4	
Fire clay	4	
Rotten coal	1	2
Coal, with 2" parting 1 foot from base	2	6
Fire clay	2	
Soft gray sandstone	32	
Black muck and slate	thin	
Sandstone and slate	25	
Gray slate	22	10
Black slate	2	6
Coal (No. 9)	5	
Fire clay	0	8
Gray sandstone		4
Total	119	

The presence of Nos. 11 and 9 coals in the above record is doubtless due to the presence of a narrow down-faulted block as shown on the map. The normal outcrop of No. 9 coal is about 1 mile to the northwest of this test hole.

Bore Hole No. 7, on A. C. Elliott Tract, 1½ Miles Southwest of Wysox on North Side of Spur Creek.

	Feet.	Inches.
Clay and gravel	11	
Red sandstone	2	
Gray sandstone	13	
Small showing of coal.		
White sandstone	11	
Sandy shale	18	
Gray slate streaked with lime	20	6
Black slate, soft	1	
Coal	1	1
Fire clay, gray	3	
White sandstone	22	
Gray slate	5	
Hard brown stone	0	4
Coal dirt	0	8
Gray and dark slate, mixed	7	5
Hard brown sandstone	1	
Gray slate	16	7
Black slate, part may be rotten coal		4
Coal	2	
Fire clay	0	8
Gray sandstone	6	
Red slate	1	
Slate	1	
Clay	2	
Sandstone streaked with slate	4	5
Gray slate	9	
Limestone	3	
Slate and sandstone } No. 11	1	
Coal with thin parting } No. 11	2	6
Coal } No. 11	2	6
Clay	1	
Total	170	

PRINCE AND WOOD MINE.

A small country mine on No. 9 coal has recently been opened just west of the Rochester and Paradise road, ¾ mile north of Daniels branch, 3 miles northwest of Rochester. The elevation of the coal at the mouth of the opening is 490 feet. The coal measured 5 feet to 5 feet 6 inches in thickness in the mine. It has a firm black slate roof 4 feet thick and hard clay floor. The dip in the mine is north 40 degrees west at about 3 per cent. grade.

The dip in the coal in the Prince and Wood mine is so strong that No. 11 coal is brought to the surface at the John Sullivan mine, ¼ mile distance due north at an elevation of 510 feet. It is quite probable that the northward dip of the rocks between the two places is influenced by the eastward extension of the Browder fault.

The coal from the Prince and Wood mine is free of parting and contains a very small amount of visible sulphur. It is all sold to the local trade, the principal part of which is at Rochester.

No. 9 coal is reported to have been worked on the south side of Green River at Green River landing, but the mine has long since been abandoned. The elevation of the coal was at low water in Green River.

No. 11 COAL.

No. 11 coal, as shown from bore holes Nos. 5 and 6, is 63 to 83 feet above No. 9. It outcrops higher in the hills in the same region where No. 9 coal occurs, and, therefore, has a much more limited area. Although it occurs up nearer the crest of the hills and has less cover above it than No. 9 coal, it is much more extensively worked in this region than No. 9.

JOHN SULLIVAN MINE.

Mr. John Sullivan is working No. 11 coal by drift a short distance east of the Rochester and Paradise road, ⅛ mile due north of the Prince and Wood mine. The elevation of the coal at the mouth of the mine is 510 feet. The coal in the main entry dips at the rate of 1 per cent. north, 35 degrees west. The following is a section at the mouth of the mine:

Section of No. 11 Coal at John Sullivan Mine.

	Feet.	Inches.
Limestone	3	
Shale	4	
Coal	1	4
Sulphur parting		1
Coal	2	6
Blue band		2
Coal	1	7
Clay floor.		
Total	12	8

The coal with parting is 5 feet 8 inches thick and is worked exclusively for local trade, the principal part of which is at Rochester.

The same coal was originally worked at the old Riverside mine opposite Green River landing on Green River, 1 mile northeast of the Sullivan opening at an elevation of 460 feet. The coal was worked out of the narrow ridge for some distance back from the river and the mine abandoned.

Another opening where No. 11 coal is worked is located ½ mile west of the Sullivan mine on the south side of the public road. The elevation of the coal is 520 feet.

WILLIAM HILL OPENING.

No. 11 coal was formerly worked at the William Hill place on the west side of the narrow ridge, ¾ mile south of South Union school. The coal at the mouth of the mine measured 7 feet in thickness with 1 foot of clay and 2½ feet of limestone above the coal. The elevation of the mouth of the mine is 460 feet.

LOUIS BENEWITZ MINE.

No. 11 coal is now being worked for local trade on the Louis Bennewitz place on the east side of Jacobs Creek, 1¼ miles due west of the William Hill opening. The full thickness of the coal including the blue band parting is 7 feet. The coal where now worked is near the surface and is colored with oxide of iron. Coal from

a nearby opening was worked 40 or 50 years ago and was the source of shop coal for the surrounding towns. The elevation of the coal at the mouth of the mine is 463 feet.

The same coal has been opened on the southwest side of the same ridge, ¾ mile east of south of the Bennewitz mine, at an elevation of 550 feet, or 87 feet higher than at the Bennewitz place. The great difference in the elevation of the two openings is due to the Browder faults which cross the ridge between the two places in a slightly northeast direction. The following is a section of the coal at the mouth of the old mine:

Section of No. 11 Coal ¾ Mile Southeast of Bennewitz Place.

	Feet.	Inches.
Bituminous shale	2	
Black slate	2	6
Coal	1	9
Clay parting		1
Coal	2	6
Blue band		3
Coal	2	6
Thickness of coal and partings	7	1

TAYLOR MINE.

No. 11 coal has been opened on the north side of Green River at a point 3 miles west of north of Rochester a few feet north of the northern boundary of the Dunmor quadrangle. The elevation of the coal at the mouth of the mine is 456 feet. The coal is worked for local trade. The following is a section at the face of the coal in the mine:

Section at Taylor Mine.

	Feet.	Inches.
Limestone	3	
Shale (gob)	1½ to 4	
Coal	2	10
Sulphur band	0½ to ¾	
Coal	2	4
Blue band		2
Coal	2	9
Clay floor.		
Thickness of coal and partings	8—1½ to 1¾	

No. 11 coal is also reported to have been struck in bore hole No. 6 on the A. O. Berryman land, 2 miles north of Rochester, on the east side of the Beaver Dam road, at a depth of 25 feet. No. 9 coal in the same hole is reported at a depth of 113 feet below the surface. The presence of these coals in this hole is doubtless the result of a small faulted block between the two Browder faults, as the normal outcrop of No. 9 is ¾ to 1 mile to the northwest.

No. 12 Coal.

The only place in the Dunmor quadrangle where No. 12 coal appears to have its normal position in the section is in the Paradise road, just west of the John Sullivan mine. At this place it appears as a thin coal close above the No. 11 limestone.

At Paradise, which is only 1½ miles north of the northern boundary of the Dunmor quadrangle, No. 12 coal is 21 feet above No. 11, and is 4 feet thick. It occurs in a bed of shale 15 feet above the top of the No. 11 limestone. The following is a section in the road just south of the landing:

Section at Paradise.

	Feet.
Sandstone to top of hill	15
Shale	35
Coal, No. 12	4
Shale	15
Limestone	4
Shale	2
Coal, No. 11.	

In bore hole No. 7, as given on a preceding page, the first coal above No. 11 is 27 feet above the latter and is only 2 feet thick.

GEOLOGIC STRUCTURE.

The structure of the rocks in the Dunmor quadrangle is fairly simple. The rocks form a monocline or a part of the southern limb of the large structural basin or trough in which the coals of Western Kentucky were formed. The general dip of the rocks is slightly

west of north, and varies from a few feet to 50 feet or more to the mile. The effect of the dip, augmented in places by faults which parallel the strike, is to carry the upper Chester rocks, which form the surface in the southern and north central parts of the quadrangle, 800 to 900 feet below the surface in the northwestern part of the quadrangle. Differential warping and settling of the strata account for part of the minor irregularities observed.

Considerable irregularity exists at the base of the Pennsylvanian series. This sometimes has the appearance of a very steep dip amounting in places to as much as 140 feet to the mile. This irregularity is really the result of erosion channels in the Chester rocks made previous to the deposition of the Pennsylvanian sediments and the latter filling the old channels in the manner in which they now occur. These old channels are usually filled with the pebble-bearing sandstone of the basal Pennsylvanian, thereby greatly increasing locally the normal thickness of this sandstone. The pre-Pennsylvanian channels become more numerous as the southeastern end of the east interior coal basin is approached.

FAULTS.

Twin Tunnels Fault.

The Twin Tunnels fault, which is described in the report on the Drakesboro quadrangle, enters the Dunmor quadrangle 1½ miles north of Penrod. Its general direction is south 86 degrees east. It is a normal fault, with the downthrow on the north. The amount of displacement in the Dunmor quadrangle is not known, but it is greatest at the point where it enters the quadrangle and apparently fades out before reaching Mud River. The fault is visible in the upturned faces of the rocks at Taggart Ford across Rocky Creek, and again in the north-south road ½ mile to the east. There is some evidence that the direction of the fault at Taggart Ford changes slightly to the north. If this is true, it may be that the displacement of the Mud River coal, which is reported at Union school house on Mud River, may be the result of the main Twin Tunnels fault. A slight

change in direction to the north at Taggart Ford would throw it in line with the Hickory Stand School fault, as shown near the eastern edge of the quadrangle. No evidence was seen of a continuation of the Twin Tunnels fault east of Mud River, in line of the Hickory Stand School fault, but most of the region along the roads traveled is covered with a thick mantle of residual material and the fault may be present but hidden.

HICKORY STAND SCHOOL FAULT.

About ½ mile north of Hickory Stand school, which is located 1 mile east of Muddy Creek, near the eastern border of the Dunmor quadrangle, is a fault with a trend of north 77 degrees east. The downthrow is on the north with a displacement of about 160 feet. East of the school house the fault disappears in a short distance and another fault with approximately the same direction develops ½ mile south of the school house. This latter fault extends eastward into the Little Muddy quadrangle, and shows in the upturned edges of the rocks on Sandy Creek, 1 mile east of Hickory Stand school.

ROCHESTER FAULT.

High up in the hill in the southern part of the town of Rochester is a fault which brings a bed of aluminous shales on the north side down on a level with a coarse grain sandstone on the south side. The fault shows in the Huntsville road, and again in the Mining City road near the crest of the hill in the southern part of the town.

The same fault is exposed in the Fairview school road, 2 miles due east of Rochester, on the west side of Panther Creek. Here the shale on the north abuts against a sandstone on the south at the same level.

The amount of displacement in the Rochester fault can only be estimated. Just south of the fault, in the Bowling Green road, is an outcrop of a thin limestone which is probably the limestone 30 to 45 feet above the Mannington coal. Upon this assumption, and the elevation of No. 9 coal in the hills 3 miles northwest of Rochester, the displacement in the fault is probably not far from 300 feet.

The direction of the fault is about north 83 degrees east. It doubtless extends west of Mud River, but its presence is hidden by a thick clay loam soil and subsoil. An eastward extension of the Rochester fault, with only a slight variation to the south, is in line with a disturbance shown in the rocks at the fair grounds at Morgantown. In that region, however, the displacement is on the south, whereas at Rochester it is on the north.

BROWDER FAULTS.

An eastward extension of the North and South Browder faults, which are described in the report on the Drakesboro quadrangles, appears in the hills north of Ennis. At the Louis Bennewitz coal opening on the east side of Jacobs Creek, and a short distance north of the North Browder fault, No. 11 coal is at an elevation of 463 feet. Just south of the South Browder fault, ¾ mile southeast of the Bennewitz place, the same coal is opened at an elevation of 550 feet, or 87 feet higher. While the dip is to the north, perhaps not over one-half of the difference in elevation is due to dip.

There is some evidence of the south fault between the Prince and Wood mine and the Sullivan mine, on the Rochester and Paradise road. At the Prince and Wood mine No. 9 coal is at an elevation of 490 feet. At the Sullivan mine, ¼ mile to the north, No. 11 coal is at an elevation of 510 feet. The normal distance between these two coals in this region is given in two well records as 64 to 85 feet. With a northward dip of 40 feet to the mile and an average interval of 75 feet between the two coals, the amount of displacement in the fault would be 65 feet.

In bore hole No. 6, located two miles north of Rochester, No. 9 coal is reported to have been struck at a depth of 113 feet with No. 11 coal 85 feet above it. The normal outcrop of N. 9 coal 1 mile north is about 440 feet, so it appears the block between the two Browder faults has a greater displacement here than in the hills north of Ennis.

At Browder, where the two faults are best studied, the amount of displacement of the South fault is 356

feet with the downthrow on the north. The North fault in the Browder mine has a displacement of 105 feet, with the downthrow on the south.

MINOR FAULTS.

Occasionally small displacements in the rocks are observed and may become of more than passing interest from the relation they occupy with reference to other faults. One of these was seen on the Rochester and Russellville road, just west of Pleasant Hill school. The rocks in the fault plane stand nearly vertical, but there is apparently only a slight displacement. The fault was not seen at any other point in the Dunmor quadrangle, but it is possible that it could have been detected at other places by a careful search. An extension of the Sharber's Store fault, which was last seen at Lees school house, 12 miles to the west in the Drakesboro quadrangle, would pass through Pleasant Hill school.

MINING AND MINING METHODS.

There are no commercial mines in operation in the area under discussion. The only mine that has ever been worked on a commercial basis was the Mud River mine, whose coal had a high reputation wherever sold. The mine was connected by a branch line from Penrod to the Owensboro and Nashville division of the Louisville & Nashville Railroad. The mine, it is claimed, was operated at a loss, and it was finally abandoned and the railroad track torn up. All efforts to revive the work have failed and the mine with its equipment has become dilapidated. In the summer of 1914 an effort was being made to clean out a part of the old mine and secure some coal that was said to have been left. A small tipple was under construction for the purpose of loading the coal into barges and float it down Mud River.

The mines in the vicinity of South Hill and Dunbar are all operated on a small basis for local trade only. The coal is shot on the solid or mined with pick. It is then loaded into small wooden cars and pushed to the outside by man power. The character of the coal in this region, with proper transportation facilities, would justify a company in fitting out a mine with modern, up-to-date equipment.

In the region underlain by Nos. 9 and 11 coals northwest of Rochester all of the mines are nothing more than small openings, where the coal is worked only a portion of the year. The coal is usually broken down by shooting on the solid and conveyed to the tipple in small cars pushed by men.

The only present means of transportation for the coals of this region is Green River. No. 11 coal is too near the surface for any extensive developments on this coal.

Within the area underlain by No. 9 coal the conditions are such that openings made along Green River could reach the coal by drift or shallow shafts and the coal loaded into bins or barges.

THE COALS OF THE LITTLE MUDDY QUADRANGLE

BY

A. F. CRIDER

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THE COALS OF THE LITTLE MUDDY QUADRANGLE

INTRODUCTION.

The present report on the coals of the Little Muddy quadrangle is one of six similar reports which the writer has prepared on quadrangles along the southern border of the western coal field. The area covered by these various reports extends from Providence, in Webster County, to a few miles east of the mouth of Big Barren River.

Nos. 9 and 11 coals, which comprise the principal source of commercial coals of Western Kentucky, do not extend as far east as the Little Muddy quadrangle. The southeast rise in the strata carries these coals to the surface at a point 6 to 8 miles northwest of the northwestern corner of this quadrangle.

In the Little Muddy quadrangle a number of coals, which further west are either absent or too thin to be of any economic interest, attain a workable thickness. Some of these coals are now being worked in the region of Morgantown for local trade, and others were formerly worked on Green River for the steamboat trade.

LOCATION.

Little Muddy quadrangle is bounded by parallels 37° and 37° 15′ and meridians 86° 30′ and 86° 45′; and embraces approximately 238 square miles. Slightly more than half of the quadrangle is in Butler County. The remainder, with the exception of about 3½ square miles in northern Todd County, lies in northwestern Warren County. Geologically, the Pennsylvanian rocks form the surface of the northern third of the quadrangle, while the surface of the remaining two-thirds consists of shales, sandstones and limestones of the Mississippian.

PREVIOUS REPORTS.

The first geological report, dealing with this region, was made by Doctor David Dale Owen, in Volume I., Old Series, Kentucky Geological Survey, pp. 160 to 162. In this report mention is made of a coal which was then mined at a point 2 miles south of Morgantown on the waters of Sandy Creek. A section is also given at the forks of Green and Barren Rivers and mention is made of coals on Lost and Indian Creeks, in Warren County.

In Volume IV. of the Owen Survey, Sidney S. Lyon, topographic assistant, discusses in a general way the geology in the region of Morgantown and gives a section of the hill 1½ miles southwest of Morgantown.

In various reports of State Inspector of Mines, Professor C. J. Norwood, the geology of the western coal field is discussed. In the last of these reports*, in which the geology of the western coal field is discussed, Prof. Norwood makes the following correlations:

Coal L (1-B), main coal formerly worked at Hawesville, "and is probably the one worked at Mud River, Empire and Aberdeen mines," the "Main Nolin" coal.

A geological map of Warren County by J. B. Hoeing was published in 1891 by the Geological Survey of Kentucky. On this map are shown the division between the Pennsylvanian and Mississippian, and the boundary line between the Chester and St. Louis groups.

TOPOGRAPHY.

The general surface of the region is an old plain, the highest remnants of which are in the southeastern portion of the quadrangle. The slope of this old plain was to the northwest at the rate of something like five feet to the mile. By the vigorous action of the streams which now carry off the surface waters of this region this old plain has become greatly dissected into ramifying ridges and valleys. The ridges, as a general rule, are narrow and in places are cut through by stream erosion. The valleys are deep and narrow, with numerous

*Report of State Inspector of Mines for 1901-02, page 324.

cliffs 100 to 300 feet in height. The width of the valleys is governed largely by the nature of the strata through which the stream passes, rather than by the volume of water or rate of the current. This is well shown in the difference in the width of the valley of Big Barren River above and below the mouth of Maxey Creek. Above this point the stream is incased in solid limestone, with little or no bottom land. Below the mouth of Maxey Creek the river bottom widens perceptibly, due to the action of the stream on the soft shales of the upper Chester.

Little Muddy Creek presents some interesting physiographic features. Its upper course is in the hard sandstones and limestones of the lower Chester, giving rise to narrow V-shaped valleys. In its middle and lower course the softer shales of the upper Chester wear readily, forming broad flat U-shaped valleys.

The direction of the stream from its source to where it strikes the basal member of the Pennsylvanian is due north. Then it takes a due east course for a distance parallel to the strike of the sandstone ridge.

Originally Little Muddy Creek took the course of Black Swamp Branch and entered Green River ¾ mile below Woodbury. It later abandoned that channel and now enters Barren River at Sproul Bend, 2 miles above Woodbury. Either the above is true or else the valley from Sproul Bend to the head of Black Swamp Branch, thence down the little valley, was at one time the channel of Barren River, which later abandoned that course for its present channel. The width of the valley west of Woodbury would suggest the idea that it has been occupied by a larger stream than either Little Muddy Creek or Black Swamp Branch.

The highest point in this quadrangle is 1 mile west of the southeastern corner, where the elevation above sea level is slightly above 780 feet. The amount of relief between this point and where Green River leaves the quadrangle is 380 feet. Some of the cliffs along Barren River are more than 300 feet high. The quadrangle taken as a unit presents a rugged type of topography. Practically the only level farming land is to be found along the stream valleys and on the narrower crests of the ridges in the southwestern portion of the quadrangle.

A striking difference is observed in the amount of cleared land along the stream valleys of Little Muddy quadrangle in comparison with that of the Dunmor quadrangle to the west. In the latter less than 1/4 of the stream valleys is cleared and under cultivation, while in the former practically every acre has been cleared and cultivated.

DRAINAGE.

The main trunk stream of this region is Green River, into which the smaller streams of the northern third of the quadrangle empty. It follows the strike of the rocks from where it enters the quadrangle to Woodbury, where it takes a northwest course and leaves the quadrangle 1½ miles below Aberdeen. It continues this general course for a distance of 10 miles below Morgantown, then makes a sharp loop and flows in a southeast direction and barely enters the quadrangle again, 4 miles west of Morgantown. The distance by river around this "Big bend" is 30 miles, while it is only 2¾ miles across it at a point west from Aberdeen.

The average width of Green River valley is slightly more than ½ mile. It meanders back and forth across its flood plain in places with very sharp curves. Lock No. 4 on Green River is located just below the mouth of Barren River. The stream is navigable throughout the year.

Barren River, the largest of the Green River tributaries, enters Green River from the south at Woodbury. While it is a very narrow stream, it is deep and with only one lock and dam, is navigable to Bowling Green, a distance of 25 miles above its mouth.

The two principal tributaries to Barren River are Little Muddy Creek and Gasper River. The former drains the west central and southwestern portions of the quadrangle and enters Barren River 2 miles above the mouth of the latter stream. Gasper River drains the south central part of the quadrangle and enters Barren River 9 miles above the mouth of the latter stream.

On upper Green River are four small lakes which have formed at the mouths of small streams entering

Green River. These are Martins Lake, Bull Lake, Upton Lake, and a smaller one on the north side of the river between Martins Lake and Bull Lake. These lakes are fed by the streams which enter them. They appear to have been formed by the silting up of their outlet by sediment deposited by Green River in time of overflow. They are all connected by outlets to Green River, but the outlets have not been sufficiently lowered to drain the lakes in times of low water in Green River.

CULTURE.

Farming has a monopoly in the occupation of the people of Little Muddy quadrangle. While the region is generally rough, the fertile valleys of Green River and the smaller streams are all cleared and support a fairly large population. The soils in the regions drained by Little Muddy Creek and Gasper River are largely derived from the decomposition of limestone rocks and are, therefore, more fertile than those of the more sandy ridge soils in the northern third of the quadrangle.

The only two towns in the quadrangle are Morgantown and Woodbury. Morgantown is located on Green River, 5 miles below the mouth of Barren River. It is the county seat of Butler County, and is a place of considerable importance, on account of its inland location. The nearest railroad on the south is at Bowling Green, 30 miles distant. Beaver Dam, 30 miles distant, is the nearest railroad point on the north. The country stores and villages over a large territory in this part of the State are reached by team from Morgantown.

Woodbury is located at the junction of Green and Barren Rivers. The Government lock No. 4 is located at this point. The town is largely supported by Government employes.

The coal mining interests in the Little Muddy quadrangle are principally located within a radius of 4 miles of Morgantown. Most of the mines are owned by farmers, who operate them solely for the local trade.

The old mine at Aberdeen was one of the early mines opened on Green River for supplying the steamboat trade. The coal was worked to the south until the

overlying sandstone cut it out and the mine was abandoned. Efforts are now being made to reopen the mine and secure some coal that was left north of the old workings.

GEOLOGY.

STRATIGRAPHY.

The rocks forming the surface outcrop of Little Muddy quadrangle belong to the Mississippian and Pennsylvanian series.

The Mississippian rocks form the surface of slightly less than two-thirds of the quadrangle and the Pennsylvanian rocks the remainder. The area of the former is shown on the map accompanying the report as the uncolored area. The division line between the two enters the quadrangle from the west at a point about due west of the mouth of Little Muddy Creek. A southern lobe of the Pennsylvanian rocks forms the crest of the narrow north-south ridge along the western boundary to a little south of Factory. The line from the northeastern end of this lobe follows the Hickory Stand School fault to near the Franklin and Morgantown road, thence in an easterly direction near the foot of the hills on the north side of Little Muddy Creek to Barren River, crossing the latter stream 1½ miles above its mouth. East of Barren River the line swings south around the high ridge between Barren River and Claylick Creek to a point due east of the mouth of Little Muddy Creek. From this point it swings to the north along the foot of the ridge to the foot hills north of Green River, then up the latter stream to near the mouth of Lost Creek. From the mouth of Lost Creek it swings to the south a short distance east of Riverside to a little south of the high ridge which rises to an elevation of 740 feet above sea level and leaves the quadrangle on the east at about the 700-foot contour line. For a distance of 1 mile on the head waters of Lost Creek, which swings back into the Little Muddy quadrangle, as shown on the map, the latter stream has cut through the Pennsylvanian strata exposing the upper member of the Mississippian.

In the region south of Green River, between Riverside and the first small stream west of Claylick Creek, are a number of small outliers of Pennsylvanian rocks which contain a thin coal near the contact between the Pennsylvanian and the Mississippian rocks.

The limestones, sandstones and shales of the Chester form the surface of the greater part of the southern two-thirds of the quadrangle. The famous white oolitic, or Bowling Green, white limestone outcrops low in the hills on the northwest side of Gasper River and on both sides of Barren River as far north as the mouth of Maxey Creek. In the forks between Barren and Gasper Rivers the oolitic stone occurs as outliers, gradually rising to the south, and finally reaching the top of the ridge on the high north-south ridge 1 mile west of the southeast corner of the quadrangle.

The Pennsylvanian strata represented in the Little Muddy quadrangle include approximately 759 feet as the maximum thickness from the base of the series to the top of the sandstone above the Mining City coal.

General Section.

		Feet	Inches.
1.	Sandstone	60 to 100	
2.	Shale	18	
3.	Coal (Mining City)	3 to 4	
4.	Shale, siliceous, in places a coarse sandstone	40	
5.	Coal	2	
6.	Shale intercalated with thin sandstones	10	
7.	Limestone	1 to 4	
8.	Shale, siliceous	40	
9.	Coal (Topmiller)	3	6
10.	Under clay	5	
11.	Shale, intercalated with thin sandstones	55	
12.	Massive sandstone	40	
13.	Shale, in places cut out by overlying sandstone	5	
14.	Coal (Aberdeen) cut out in places by overlying sandstone	3 to 4	
15.	Black schistose shale	35	
16.	Coal	1	

		Feet.	Inches.
17.	Black shale	40	
18.	Black aluminous shale grading downward into siliceous slate or sheety sandstone	25	
19.	Coal (Foster)	2	6
20.	Siliceous gray slate	18	
21.	Black shale	2	
22.	Coal (Amos)	2	2
23.	Sandstone, grading downward into slate	10 to 20	
24.	Coal (Gidcomb)	4	
25.	Sandstone	20	
26.	Coal	thin	
27.	Sandstone	20	
28.	Coal	thin	
29.	Siliceous shale	15	
30.	Sandstone, thin and thick bedded	37	
31.	Schistose black shale, containing bands of carbonate of iron	28	
32.	Hard black shale intercalated with thin sandstones	60	
33.	Sandstone	6	
34.	Coal	thin	
35.	Sandstone (Bee Spring)	20	
36.	Coal (Main Nolin)	3	
37.	Shale, siliceous above and becoming calcareous below	60	
38.	Limestone consisting mostly of rounded fragments of limestone 3 to 4 inches in diameter cemented with calcium carbonate (Chester)	8 to 10	
39.	Shale.		
	Total	691 to 759	2

The general section of the Pennsylvanian given above was made from surface outcrops in different parts of the quadrangle. From 1 to 14 of the general section was made in the hills north of Morgantown. From the Aberdeen coal to the Amos coal was made on the east side of Green River between Aberdeen and Big Bull Creek. The remainder of the section was made from exposures at Woodbury and in the Forks between Green and Barren Rivers.

What is perhaps the highest exposed limestone of the Chester is seen on the Bowling Green road, 1½ miles southeast of Riverside. It occurs just below a bed of calcareous shales of Chester age. It consists of rounded pebbles of limestone cemented with calcium carbonate into a conglomeratic mass, marking the place of an unconformity in the Chester.

At a point 60 feet above the limestone is a thin coal under a coarse sandstone, which is 20 feet thick where it shows in the road, but increases in thickness on the ridge to the east. Immediately above the sandstone is another thin coal. The sandstone between the two thin coals is doubtless the equivalent of the Bee Spring sandstone of Edmonson and Grayson Counties.*

The basal pebble-bearing sandstone of the Pennsylvanian is absent in the Little Muddy quadrangle and the Bee Spring sandstone forms the first sandstone above the top of the Chester. A short distance east of the Little Muddy quadrangle the basal pebble-bearing sandstone is again present. Its presence along the southern border of the coal field in the region to the east and to a less extent to the west of the Little Muddy quadrangle, is chiefly confined to old erosion channels in the Chester. During the erosion interval that prevailed between the close of Chester time and the beginning of Pennsylvanian deposition more or less of the Chester rocks were removed by erosion, which accounts for the lack of uniformity in the upper Chester of this region. It is the exception rather than the rule in this region to find the full thickness of the Chester. A striking example of the variation of the upper Chester is seen on the Bowling Green road between Claylick Creek and a point 1½ miles southeast of Riverside.

Between Riverside and Claylick Creek are a number of small outliers of the Pennsylvanian with the Bee Spring sandstone and the thin coal close under it capping the hills. On the Bowling Green road, 1½ miles southeast of Riverside, are 60 feet of shale just below the Bee Spring sandstone with a conglomeratic limestone

*Kentucky Geological Survey, Vol. II, Series IV, page 27.

8 to 10 feet thick below the 60-foot shale bed. Below the limestone for 50 to 60 feet are blue calcareous shales.

Close under the Bee Spring sandstone which caps the tops of the two small rises between Riverside and Claylick Creek and less than 2 miles from the above mentioned place is a thick massive sandstone 50 or 60 feet thick, which is probably the third sandstone from the base of the Chester. The 120 feet or more of Chester shales and the intervening conglomeratic limestone, as shown southeast of Riverside, were removed by erosion previous to the deposition of the Pennsylvanian.

The only quartz pebbles seen near the contact between the Chester and the overlying Pennsylvanian rocks east of Barren River are on the high ridge between Barren River and the first stream west of Claylick Creek. The pebbles on this ridge are small, the greater portion being less than ½ inch in diameter. They have the appearance of having been derived from the Bee Spring sandstone which is conglomeratic in places, rather than from the basal sandstone of the Pennsylvanian. These rounded quartz pebbles are mixed with more angular fragments of limestone, with the lime largely leached out, and chert. The limestone and chert were brought down to their present locations by Barren River and mixed with the quartz pebbles from the Bee Spring sandstone.

These quartz, limestone and chert pebbles occur on the hills rising to a height of 600 feet above sea level, indicating that at one time Barren and Green Rivers flowed at this elevation.

West of Barren River the Bee Spring sandstone forms the base of the Pennsylvanian to the western edge of the quadrangle. Neither the coal below nor above the sandstone attains a thickness of a workable coal in this region.

CHESTER COAL.

A coal that is only of scientific interest occurs in this region below what is probably the third limestones from the base of the Chester. Between the limestone and the coal is a bed of dark blue calcareous shales 5 to 8 feet in thickness. The coal is 10 to 12 inches thick and is of no economic importance.

NOLIN COAL.

In the main section of this report two coals are given in the lower part of the section. The lower coal occurs close under and the upper on top of the Bee Spring sandstone. In the first volume of the Owen Survey, Dr. D. D. Owen described the lower coal as the "Main Nolin Coal," a name which is retained in this report. In Edmonson and Grayson Counties it is described by P. N. Moore in Volume II., New Series, Kentucky Geological Survey, as being 20 to 30 feet above the top of the Chester limestone. In the region southeast of Riverside, in the Little Muddy quadrangle, there is a 60-foot interval of Chester shale between the Nolin coal and the highest limestone of the Chester.

The Nolin coal shows in the Bowling Green road ½ mile east of Riverside, where the following section was obtained. The elevation of the coal is 660 feet.

Section ½ Mile East of Riverside.

	Feet.
Sandstone (Bee Spring)	20
Shale	3
Coal (Nolin)	2
Shale to bottom of slope.	

The same coal has been opened ½ mile south of the above mentioned outcrop on the farm of John Richards, at an elevation of 660 feet. The coal is reported to be 4 feet thick with 6 inches of bone coal at the bottom. Three to four feet of shale intervenes between the top of the coal and the base of Bee Spring sandstone.

The same coal outcrops again in the Bowling Green road ½ mile southeast of the Richards opening. It occurs close under the Bee Spring sandstone at an elevation of 700 feet.

What appears to be a lower coal than the Nolin coal has been opened on the north side of Lost Creek, about 1 mile from the mouth of that stream. It occurs 30 feet

below the base of the Bee Spring sandstone. The interval between the coal and the sandstone is filled with shale. The immediate roof of the coal is a band of carbonate of iron 4 to 6 inches in thickness. It has a hard black slate roof. The thickness of the coal where opened in 20 inches. It is an excellent quality of coal and is being worked to some extent for local use.

A coal outcrop at the mouth of Lost Creek is shown on the geological map of Warren County by J. B. Hoeing. In an unpublished report by Col. M. H. Crump, of Bowling Green, the coal is described as being 10 to 30 inches thick. Before the raising of the dam at Woodbury the coal was above low water in Green River and was worked. The raising of the water level in the river flooded the mine and it was abandoned. In describing the coal Col. Crump says:

"This is quite likely a sub-conglomerate coal, and has always been held in high repute by the local smiths who have used it for years."

GIDCOMB COAL.

On the northeast side of Green River, 2½ miles above Morgantown, J. W. Gidcomb has opened a mine on a coal which occurs about 186 feet above the top of the Bee Spring sandstone. The elevation of the coal is 470 feet above sea level.

The coal contains a blue clay parting 4 to 8 inches thick. The floor of the coal is a sandstone. The roof is a hard siliceous shale which contains perfect impressions of large and small reeds, roseate flowers, ferns and the remains of trunks of trees, some of which are 18 inches in diameter.

The quality of the coal is said to be very poor. Its use in steamboat boilers was abandoned on account of the great amount of ash and its poor heating qualities.

The following section of the high bluff at this place shows the relationship of the Gidcomb coal to the two thin coals below and the Amos, Foster, Topmiller and Aberdeen coals above:

Section of Bluff at Gidcomb's Mine.

	Feet.	Inches.
Shale	20	
Limestone	2	
Shale	10	
Showing of coal (Cates Coal ?)	....	
Shale	25	
Coal (Topmiller)	3	
Shale	25	
Cliff-forming sandstone	75	
Place of Aberdeen coal	Absent	
Dark shale weathering pale gray with the coal near the center	60	
Sandy slate and sandstone containing the Amos and Foster coals	30 to 40	
Coal (Gidcomb): Shale roof. / Bone 4″ / Coal 12″ / Blue clay 4″ to 8″ / Coal 20″ / Sandstone floor.	3 ft. 4 in. to 3	8
Sandstone	20	
Coal	thin	
Sandstone	20	
Coal	thin	
Siliceous shale to low water in Green river	15	

AMOS COAL.

The next coal above the Gidcomb coal is a thin coal which is known as the Amos coal. It has been opened on the west side of Big Bull Creek, 2 miles above the mouth of that stream. The elevation of the coal where opened is 518 feet above sea level. The position of the coal is 10 to 15 feet above the Gidcomb coal and 18 to 20 feet below the Foster coal, next to be described. It is a thin coal only 26 inches thick, but it is of excellent quality. It is free from partings and comes out in large blocks the thickness of the seam. It is a black jet color and does not soil the hands in handling. The following is a section of the hill where the coal outcrops:

Section at Amos Mine.

	Feet.	Inches.
Thin bedded sandstone	40	
Hard sandstone	2	
Siliceous slate	15	
Black slate full of reed impressions	2	
Coal (Amos)	2	2
Sandstone	20	

The Amos coal thins to the west, and is not worked west of Big Bull Creek. At the old Martin mine, on the east fork of Bull Creek, it is only 1½ feet thick. At the latter place it is 20 feet below the Foster coal.

At the Foster and Fields mines, on the west fork of Bull Creek, the Amos coal is only 18 inches thick. It has a siliceous slate roof and clay floor.

FOSTER COAL.

The Foster coal lies 18 to 20 feet above the Amos coal and 180 feet below the Topmiller coal. The Aberdeen coal, next to be described, where present comes between the Foster and the Topmiller coals. It has never been found southeast of Aberdeen.

The Foster coal is worked at a number of openings on Bull Creek. It is hauled by wagon across the high ridges to Green River at Foster's Landing, where it is loaded into barges and shipped to Bowling Green and other places on Green and Barren Rivers.

The coal occurs under a hard siliceous slate or sandstone with a siliceous slate floor. It averages 30 inches in thickness. The lower half of the seam is a hard, brittle, non-smut, black shiny coal, which comes out in large blocks. It has very little sulphur and is regarded as an excellent heating coal. The upper half comes out in smaller blocks and is less pure than the lower part. There is generally a thin band of bony coal at the bottom of the seam.

A sample of the Foster coal from J. H. Field's mine, collected by the writer and analyzed by J. S. McHargue in the laboratory of the Kentucky Geological Survey, gave the following results:

Analysis of Foster Coal.

Laboratory No. G-3667.

	As received.	Air dried.
Moisture	8.61	2.99
Volatile matter	37.87	40.20
Fixed carbon	47.13	50.03
Ash	6.39	6.78
	100.00	100.00
Sulphur	3.75	3.36
B. t. u.	13240	13434

The above analysis shows a relatively small amount of ash and a fair heating value as indicated by the B. t. u. The mine where the sample was taken had been worked to the property line and pillars were being pulled preparatory to its abandonment. The sample was taken from an old pillar on the main entry.

The dip of the coal from Bull Creek to Aberdeen, as determined by the Aberdeen coal, is 55 feet to the mile. At this rate of dip the Foster coal at Morgantown would be 120 feet below the 400-foot contour line, which is slightly below the level of the bottom land.

ABERDEEN COAL.

The Aberdeen coal is the next workable coal above the Foster coal. The vertical distance between the two coals is from 90 to 100 feet. For a distance of 75 feet below the Aberdeen coal is a black bituminous shale which weathers to a pale gray. Near the center of this shale bed is a thin coal 12 inches in thickness. The thin coal outcrops in the road above the ice factory at Morgantown.

Above the Aberdeen coal, for a distance of 40 to 50 feet, is a coarse cliff-forming sandstone which in places is separated from the coal by a bed of shale, which thickens to the north. There is a well-marked erosional unconformity at the base of the sandstone, which accounts for the thickening and thinning of the shale overlying the coal. In places the shale and a part or the entire thickness of the coal is cut out by the sandstone.

The coal is all cut out southeast of a line drawn through Middle Ferry and having a bearing of approximately N. 35 degrees east.

In the old East Aberdeen mine the sandstone formed the immediate roof of the coal, which was worked to the southeast until the sandstone cut out the coal entirely. In the old Aberdeen mine 5 to 6 feet of shale intervenes between the coal and the sandstone.

An opening was made at the base of the sandstone a short distance above the Middle Ferry in the summer of 1914 in an effort to find the coal. Thin irregular streaks of coal were found as reworked material in the lower part of the sandstone, showing that the coal had been eroded by the action of strong currents and redeposited as a part of the sandstone.

At Morgantown all traces of the coal at the base of the sandstone are absent. The heavy bedded sandstone is traceable through the hills to Bull Creek, but at no place was any trace of the coal found. There is some question as to whether the coal was ever deposited southeast of Welch Creek. The coal was either formed in local basins, or, after its formation, it was eroded and in places entirely cut out, giving it now the appearance of having been formed in local basins. The widespread erosional unconformity at the base of the overlying sandstone lends force to the theory that it was formed over an extensive area and then removed over local areas before the deposition of the overlying sandstone.

James H. Gardner, while connected with the Kentucky Geological Survey, spent some time in tracing the outcrop line of the Elm Lick coal of Ohio County. In a private letter from Mr. Gardner he states that he traced the outcrop of the Elm Lick coal to Aberdeen, and the coal described in this report as the Aberdeen coal is the equivalent of the Elm Lick coal. The writer traced the Aberdeen coal to Flenerville, thence to Baizetown, and as far as Elm Lick Creek, in Ohio County. The Aberdeen coal is also the equivalent of the Mud River coal, in the Dunmor quadrangle.

In the region of Mt. Pleasant Church, in Ohio County, and to the north of that point the coal is made

up of an upper and lower bench, with a clay parting near the middle of the seam.

In the East Aberdeen mine there is a marked distinction between the upper and lower benches, but the clay parting is absent. The lower half of the coal is a jet black, non-smut coal, which comes out in large blocks. The upper half is an ordinary dull black bituminous coal.

On a recent visit to Aberdeen the old mine was being pumped out preparatory to getting some coal that is reported to have been left. In this mine the following section was obtained:

Section in Old Aberdeen Mine.

	Feet.	Inches.
Sandstone (Aberdeen).		
Black shale	4 to 6	
Coal, upper bench	2	6
Shaly coal parting	0	4 to 10
Coal, about	1	6

The lower coal was partially covered with water and could not be measured accurately.

The Aberdeen coal has never been opened west of Green River. The Aberdeen sandstone, which forms the steep cliffs in the region of Aberdeen, forms the bluff on which Morgantown is situated. The base of the sandstone goes under cover just below the lower ferry at Aberdeen. The strong northwest dip of 60 feet to the mile brings the base of the sandstone 75 feet above low water at Morgantown. A fault in the rocks near the junction of the Bowling Green and Rochester roads, ½ mile southwest of Morgantown, depresses the strata on the south and the Aberdeen sandstone is not recognized south of the fault.

TOPMILLER COAL.

The next coal above the Aberdeen coal is known in the Little Muddy quadrangle as the Topmiller coal. It is the equivalent of the Dunbar coal of the Dunmor quadrangle, and the Mannington and Dawson Springs coal of the Nortonville and Dawson Springs quadrangles.

The interval from the Aberdeen coal up to the Topmiller coal is about 100 feet.

The geologic horizon of the coal in this region, as further west, is marked by a very persistent limestone which occurs 30 to 40 feet above the coal. The interval between the coal and the limestone is made up of shale. The thickness of the coal in this region is not as great as it is in the Dunmor quadrangle. The minimum thickness is slightly less than 3 feet, with a maximum thickness of 3½ feet.

The roof of the coal is a gray shale which contains excellent specimens of ferns, reeds and other organic remains.

A number of openings have been made on this coal on the Topmiller property on the public road, 2½ miles due east of Morgantown. The elevation of the coal where worked is 614 feet. The coal is hauled from the mine to the river in wagons and loaded into barges and shipped to markets on Green and Barren rivers.

On the same road just west of Johnson's store the same coal is worked for local use at an elevation of 640 feet.

What appears to be the Topmiller coal has been opened on the Gillam place, 1½ miles south of west of Morgantown, on the north side of the Rochester road. In the Rochester road, 70 feet above the coal, is a hard siliceous chert which breaks up in small cubical blocks.

The following is a section of the face of the coal which was sampled and analyzed in the laboratory of the U. S. Bureau of Mines:

Secticn in Gillam Mine.

		Feet.	Inches.
	Roof—Bluish-gray shale.		
1.	Bony coal		2
2.	Coal, soft		7
3.	Mother coal		¼
4.	Coal	2	7
5.	Bony coal, high in ash		5
	Total	3	9¼

Analysis of Topmiller Coal From the Gillam Opening.

		Coal air dried	Coal as recetved	Coal moisture free	Coal moisture and ash free
	Moisture	5.55	8.76		
Proximate analysis.	Volatile matter	40.95	39.56	43.36	47.28
	Fixed carbon	45.67	44.12	48.35	52.72
	Ash	7.83	7.56	8.29	
		100.00	100.00	100.00	100.00
	Hydrogen	5.54	5.73	5.22	5.69
	Carbon	69.44	67.08	73.52	80.17
Ultimate analysis.	Nitrogen	1.67	1.61	1.76	1.92
	Oxygen	11.92	14.54	7.40	8.07
	Sulphur	3.60	3.48	3.81	4.15
	Ash	7.83	7.56	8.29	
		100.00	100.00	100.00	100.00
Calorific value determined.	Calories	6989	6751	7399	8068
	B. t. u.	12580	12152	13318	14522
Calorific value calculated from ultimate analysis.	Calories		6846		
	B. t. u.		12323		

The above analysis is a composite of two analyses. The bony coal at top and bottom of the seam was included in one sample and excluded in the other.

In the point of the hill on the Bowling Green road, 2 miles southwest of Morgantown, the Topmiller coal has been opened at a number of places which are now abandoned. The limestone 2 feet in thickness occurs 36 feet above the coal. The elevation of the limestone is 520 feet, or 10 feet higher than the siliceous chert horizon on the Rochester road, ¾ mile to the northwest.

What is doubtless the Topmiller coal has been opened south of the Rochester road, 1¼ mile south of Bearwallow school. The elevation of the coal is 465 feet. The roof of the coal is a gray shale containing impressions of strap leaves and perhaps other organic remains. The coal at the mouth of the entry where measured is 3½ feet in thickness. The under clay is a siliceous gray clay grading downward into a sandstone.

MINING CITY COAL.

The coal that is most extensively mined in the Little Muddy quadrangle is the coal that was originally worked extensively at Mining City, which is located on Green River, $1\frac{1}{2}$ miles west of the western edge of the Little Muddy quadrangle.

It outcrops in the hills 1 to 2 miles northwest of Morgantown at elevations of 570 to 600 feet. The northwest dip of the coal carries it deeper under cover to the northwest, and throws it above the highest hills south of Renfrow Creek. At only one place was the coal found to outcrop south of the Rochester road leading out of Morgantown.

From the Blancett mine due west to Mining City, a distance of 4 miles, the dip is $38\frac{1}{2}$ feet to the mile.

The Mining City coal is one of the easiest coals to determine in this region. It is characterized by a rotten limestone or marl which in places forms the immediate roof of the coal. In other places it is separated from the coal by a bed of soft plastic clay with a maximum thickness of 18 inches. The limestone or marl varies from 1 to 18 inches in thickness. Where it is so thick it is often found with a shale parting near the center. In places it contains thin bands of coal near the bottom. The rotten limestone or marl is largely composed of macerated marine fossils, and is known as the "peniwinkle rock."

The main roof of the coal is a hard shale, which varies from 5 to 20 feet in thickness. Resting on the shale is a coarse-grained sandstone which forms a steep escarpment where it comes to the surface. The thickness of the sandstone varies from 50 to 100 feet. In prospecting for the coal it should be looked for from 8 to 20 feet below the base of this cliff-forming sandstone.

The coal is moderately soft, of a jet black color, and contains thin mother coal partings. At the bottom of the seam is a thin band of bone coal with a maximum thickness of 4 inches. In mining the coal the bone coal is mixed with the better grade and the entire seam is sold

FLOWERS' OPENING.

F. M. Flowers is working the Mining City coal on the headwaters of a branch of Renfrow Creek, 1 mile a little south of west of Limestone school. The elevation of the coal is 535 feet. The following is a section at the face of the coal:

Section in Flowers' Opening.

	Feet.	Inches.
Shale.		
Fossiliferous marl	0	1 to 6
Coal	2	8
Coal, very brittle, black jet color	1	
Bone coal		4
Fire clay.		

Beginning at Allen's Hill, 1 mile northwest of Morgantown and extending 1 mile to the west, no less than twelve openings have been made on the Mining City coal. At the Harlan Raymer opening on the west side of Allen's Hill, the coal is at an elevation of 580 feet. The following section shows the relationship of the coal to the thick sandstone above:

Section at Harlan Raymer Opening.

	Feet.	Inches.
Sandstone, coarse, heavy bedded	50	
Shale	3 to 5	
Rotten limestone full of macerated shells	0	8
Coal	3 ft. 2" to 4	
Bone coal	0	½
Hard fire clay base.		

BLANCETT MINE.

W. T. Blancett is working the Mining City coal at a point $1\frac{1}{2}$ miles due west of Morgantown on the headwaters of Little Sandy Creek. The elevation of the coal at the mouth of the mine is 575 feet. The coal in this mine is harder than at most of the openings in the district. It is opened on the west side of the ridge 18 to 20 feet below the base of the heavy sandstone which forms a steep escarpment to the north.

The coal is 3½ to 4 feet in thickness, with a very thin band of bone coal at the bottom and the rotten limestone or fossiliferous marl above.

A sample of the coal collected by the writer and analyzed by J. S. McHargue in the laboratory of the Kentucky Geological Survey gave the following results:

Analysis of Mining City Coal.

Laboratory No. G-3665.

	As received.	Air dried.
Moisture	6.14	2.43
Volatile matter	46.14	47.97
Fixed carbon	42.63	44.31
Ash	5.09	5.29
	100.00	100.00
Sulphur	3.75	3.90
B. t. u.	13240	13765

The above analysis shows a high volatile, low carbon compound, with a relatively low ash and high sulphur content. The heating value of the coal as expressed by the B. t. u., shows it to be an excellent quality of coal.

The coal from the various mines of the district is all consumed locally. The county court house and jail at Morgantown are supplied by coal from the local mines. Another large consumer of coal is the electric light and water plant at Morgantown. A part of the coal for this plant has to be shipped in by river from the mines below Cromwell.

GEOLOGIC STRUCTURE.

By the geologic structure of a region is meant the arrangement and position of the rocks. The original position of the strata in the Little Muddy quadrangle was horizontal, or nearly so. The slight inclination of the beds was produced by the slope of the surface on which the sediments were deposited.

The original horizontality of the beds was subsequently disturbed by a slight warping of the beds. In certain localities the rocks have been further disturbed by fractures or faults. The original features of the

surface have been greatly disguised, displacements hidden, and the entire area reduced through the long continued wear of running waters. Particles of sand and larger rock fragments which are carried by the streams when moving with rapidity serve to accelerate the cutting power of the streams.

DIP.

The normal dip of the rocks, except where locally disturbed by faults, is to the center of the great basin in which the coals of Central Interior coal field were formed. The southern border of this basin crosses Little Muddy quadrangle in a general east-west direction just north of the center. The position of the quadrangle with reference to the entire basin is near the southeastern extremity, so that the normal dip is to the northwest.

The direction of the greatest dip is approximately north 45 degrees west, or about parallel to the general direction of Green River from Woodbury to where it leaves the quadrangle. Along this line the dip from Foster's landing to Aberdeen is 55 feet to the mile. From Morgantown to Aberdeen the dip is 38 feet to the mile.

Along the line of contact between the Pennsylvanian and the Mississippian there is a wide variation in degree and direction of the apparent dip due to the erosional unconformity at the base of the Pennsylvanian.

In the region of the faults, to be described later, the dip of the rocks is accentuated as a result of the faults.

FAULTS.

HICKORY STAND SCHOOL FAULT.

The Hickory Stand School fault enters Little Muddy quadrangle from the west at a point nearly due west of the mouth of Little Muddy Creek. The general direction of the fault is north 75 degrees east. It is a normal fault with the downthrow on the north. The Pennsylvanian rocks on the north are depressed with reference to the Mississipian on the south. The greatest dis-

placement is on Sandy Creek and amounts to approximately 160 feet. East of Sandy Creek the amount of displacement becomes less, and before Green River is reached the surface appearances of the fault have disappeared. It is possible, however, that the variation in the section of the hill at Woodbury and that of the high hill between the forks of Green and Barren Rivers is the result of the continuation of the fault which would pass between these two points.

WAVERLY SCHOOL FAULT.

At the foot of the high ridge just west of Waverly school house is a fault having a general trend at that place of north 12 degrees west. The upturned edges of the sandstone dipping steeply to the east indicate a downthrow on the east. The fault was seen at only one place, so that the general direction may vary slightly from the one reading.

From the presence of a heavy bedded sandstone on the east side of Claylick Creek, 1 mile south of Upton's store, in Northern Warren County, and its absence on the west side of the creek, it is possible that the southward extension of the Waverly school fault, has affected the unity of the strata in northern Warren County.

A point on Barren River where the southern extension of the fault would intersect the river is a well-defined arch in the strata. The projected line of the fault is parallel to the axis of the anticline with the long limb on the east and the short limb on the west. Whether there is any connection between the fault and the anticline could be determined only by a careful study of the region between Barren and Green Rivers along the projected line of the fault.

MORGANTOWN FAULT.

Just outside of Morgantown, where the Rochester and Bowling Green roads separate, the rocks are dipping north at a high degree, indicating the presence of a fault. The disturbance in the strata is visible for a short distance only.